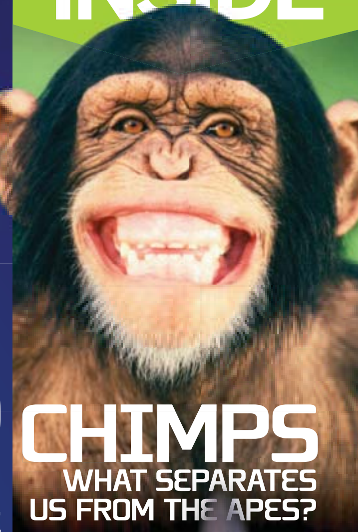
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE · ENVIRONMENT · TECHNOLOGY · TRANSPORT · HISTORY · SPACE



INSIDE

CHIMPS
WHAT SEPARATES US FROM THE APES?

SPACE TELESCOPES
How do these giant instruments enable us to look back in time?



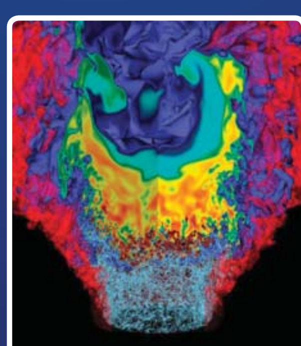



AMAZING CHEMISTRY

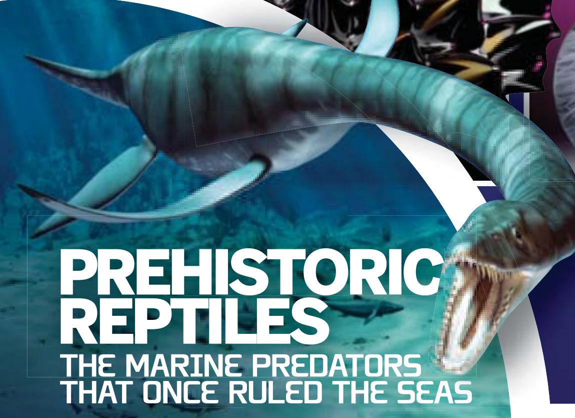
THE COOL SCIENCE BEHIND CHEMICAL REACTIONS

MAGNESIUM FLARES · THERMITE REACTIONS · ROCKET CANDY & MORE





THE VIKINGS
Discover how these Norse warriors changed the world



PREHISTORIC REPTILES
THE MARINE PREDATORS THAT ONCE RULED THE SEAS

+ LEARN ABOUT

- STEM CELLS
- OSTRICHES
- COMAS
- EUROPA
- MORAY EELS
- DOG NOSES
- CAR BATTERIES
- DEFORESTATION
- FIRE HYDRANTS
- CARGO PLANES
- PETER HIGGS
- CT SCANNERS

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HOW IT WORKS

ISSUE 45

WELCOME

The magazine that feeds minds!

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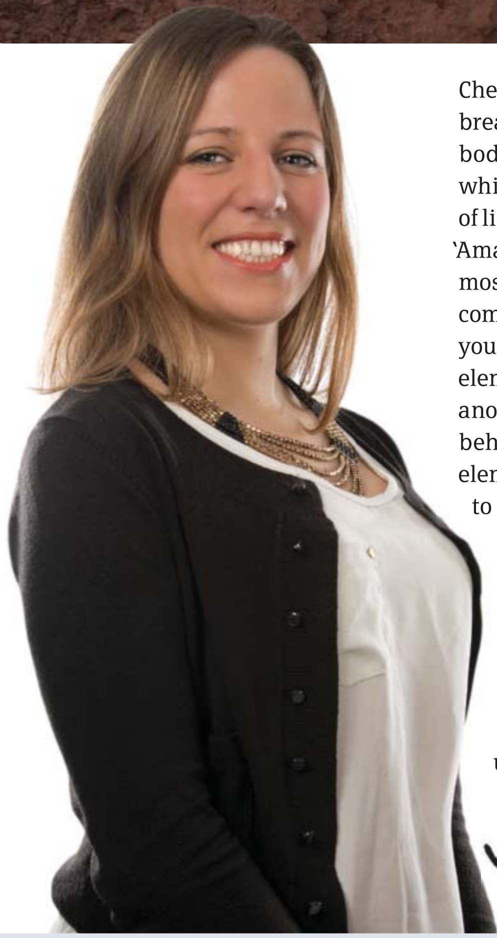
Known by locals as the 'Door to Hell' this natural gas crater in Turkmenistan has been ablaze since 1971



Chemistry is everywhere – it is the air we breathe, it is the food we eat, it is the stuff our bodies are made of, it is the universe. And yet while chemistry has a hand in every 'element' of life it is also deceptively simple. This issue's 'Amazing chemistry' feature takes some of the most fascinating – and often explosive – compound reactions and breaks them down for you into clear recipes that reveal the various elements involved, how they react with one another and – importantly – why they can behave so violently. You'll discover exactly how elements respond when combined with others to create substances in their purest form or new compounds. Most chemical reactions produce light, heat and even sound energy and we've explained ten of the most exciting we could find. We've also detailed a few of the 'less deadly' offerings you'll find at home, as well as info about everyday chemistry such as that used in batteries, bread-making and more.

Helen Laidlaw
Editor

What's in store…

The huge amount of information in each issue of How It Works is organised into these key sections:

Science
Uncover the world's most amazing physics, chemistry and biology

Technology
Discover the inner workings of cool gadgets and engineering marvels

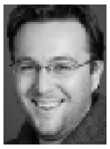
Transport
Everything from the fastest cars to the most advanced aircraft

Space
Learn about all things cosmic in the section that's truly out of this world

Environment
Explore the amazing natural wonders to be found on planet Earth

History
Step back in time and find out how things used to work in the past

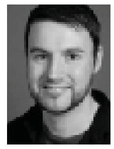
Meet the team…



Robert
Features Editor
For 300 years, the Vikings carried Scandinavian culture around the world. Discover their legacy on page 72…

Helen
Senior Art Editor
I now know that rubbing batteries doesn't make them last longer thanks to the 'Tech myths' feature!

Ben
Features Editor
Chimps must be Earth's most fascinating creatures – it's amazing to think we share at least 90 per cent of their DNA.



Adam
Senior Sub Editor
Putting the controversy aside it was great to get some insight into stem cells' huge medical potential.

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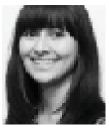
The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the writers in this month's edition of **How It Works…**

Alexandra Cheung
Stem cells



They're something of a hot potato in the scientific community, but Alex is here to put these miracle cells under the microscope and show us why they're packed with the potential to cure many ailments.

Jo Carlowe
Comas

With a degree in psychology and expertise writing on health and science for a number of national publications, comas seemed like a natural subject for Jo to explain in her very first HIW article.

Luis Villazon
Chimpanzees

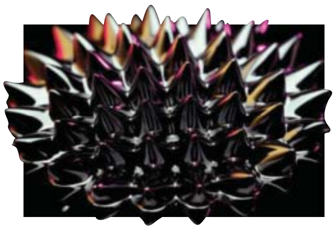
This month How It Works' wildlife expert Luis is shining a light on the world of chimpanzees, focusing on the behaviour and traits that explain why they're humanity's closest relatives.

Rik Sargent
Chemical reactions

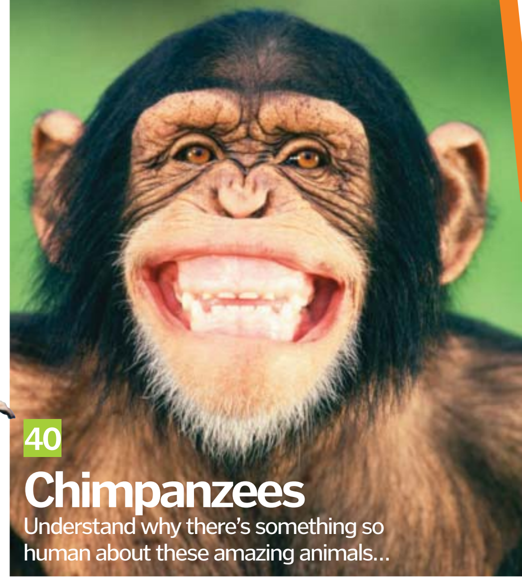
Taking a closer look at the more explosive side of science, Rik reveals the secrets of some of the most exciting – and often explosive – reactions taking place in and out of the lab, as well as a few of the most deadly.

How does the Phalanx take down missiles? Find out on page 32

14 AMAZING CHEMISTRY



"The way atoms behave determines everything from the food we eat to how our genes work"



REGULARS

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Supermassive hitchhiker discovered

A recently spotted giant black hole is believed to have 'hitched a ride' in a nearby galaxy 250 million light years from Earth

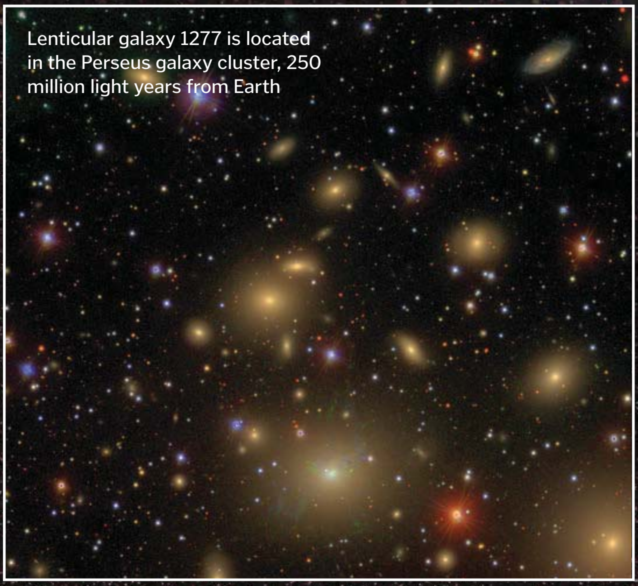
One of the biggest black holes ever recorded may have been ejected from one galaxy and 'picked up' by another. The unprecedented theory was proposed after astronomers found it accounted for a whopping 14 per cent of NGC 1277's total galactic mass, blowing through a previously held belief that galactic black holes averaged only 0.1 per cent of a galaxy's total mass.

This mismatched pairing of a normal galaxy in the Perseus cluster with a black hole 17 billion times the mass of the Sun caused scientists to scour the surrounding area and calculate the gravitational interactions between local astronomical objects. During their search they found a giant galaxy – NGC 1275 – that could have supported the black hole about 325,000 light years from NGC 1277.

This spurred the astronomers to run some computer simulations to study the potential ways 1277's black hole might have 'jumped' from 1275. The result was a theory in which 1275 was formed from two galaxies with 10-billion-solar-mass black holes which, during the merger, caused one of them to be ejected at phenomenal speed. This runaway black hole was then assimilated by NGC 1277.

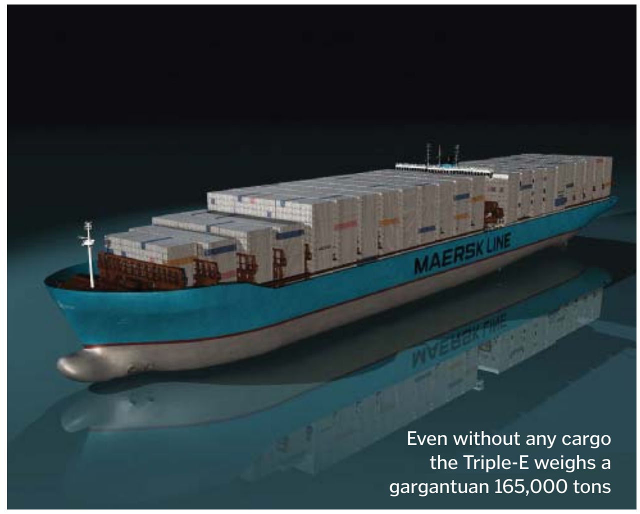
Speaking on the supermassive black hole at the heart of 1277, one of the paper's authors – Erin Bonning – said it is an "extraordinary black hole in an ordinary galaxy".

Despite the team's theory being backed up by a number of computer simulations, the complex chain of events that it rests upon have been questioned by some in the astrophysical community. Avi Loeb of the Harvard-Smithsonian Center for Astrophysics, MA, commented: "Several rare events [like those suggested by the team] together are unlikely. I would think that there are more likely ways of achieving the same result."


Lenticular galaxy 1277 is located in the Perseus galaxy cluster, 250 million light years from Earth

"The black hole accounted for a whopping 14 per cent of NGC 1277's total galactic mass"

The previous record for a black hole's percentage of total galactic mass is 11 per cent



Even without any cargo the Triple-E weighs a gargantuan 165,000 tons

Giant freighter unveiled

International shipping line Maersk reveals the latest model in its fleet – and it's a whopper!

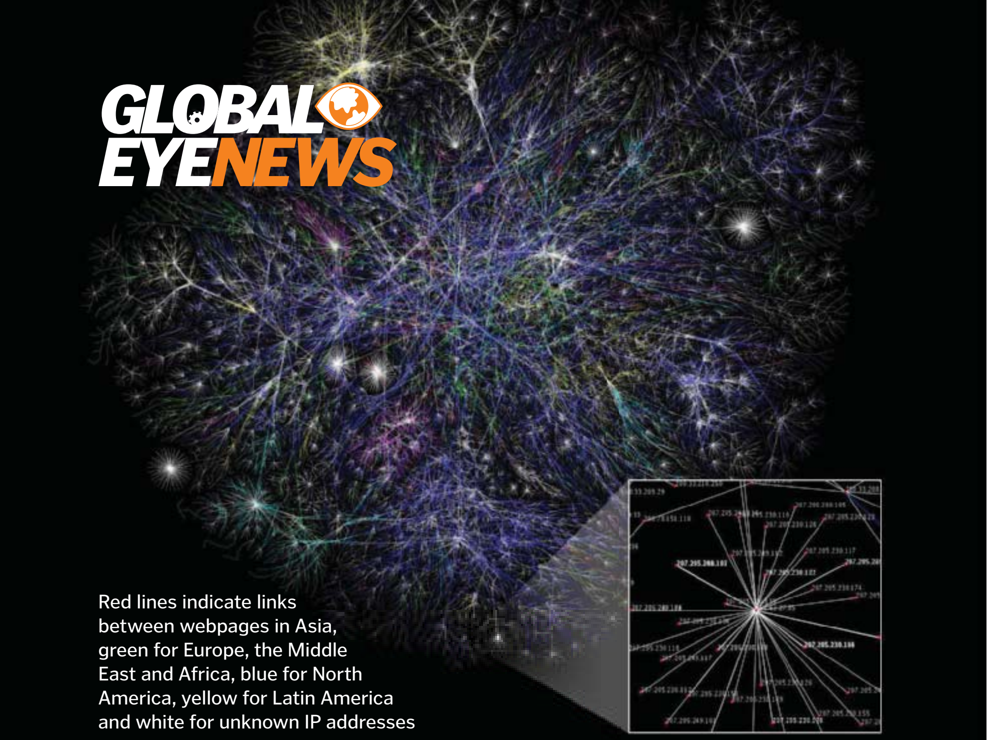
A quarter of a mile long and taller than the London Olympic Stadium, to call the Triple-E cargo ship from global shipping company Maersk big is a huge understatement. Constructed from eight times the quantity of steel in the Eiffel Tower, measuring 400 metres (1,312 feet) in length and able to carry up to 18,000 six-metre (20-foot) containers (TEUs), the Triple-E is a real sea monster.

The Triple-E has been announced to launch in June 2013, an event that will see it overtake the current largest container vessel in the world: the 396-metre (1,299-foot)-long CMA CGM Marco Polo. Upon hitting the water the Triple-E will run what is known as a 'pendulum service' between Asia and Europe, carrying thousands of tons of goods and depositing them in some of Europe's largest docks.

Indeed, the sheer size of the Triple-E is set to become a considerable challenge for existing dockyards over the next couple of years, with many sites needing to build new wharves, deepen existing harbours and acquire modern high-speed cranes to accommodate the supership.

Interestingly, despite the Triple-E being the largest container vessel on Earth, according to Maersk it will also be the most environmentally friendly, with the three 'E's that feature in its name standing for: 'Economy of scale', 'Energy efficiency' and 'Environmentally improved'. These eco-friendly credentials are coming courtesy of redesigned engines, an improved waste-heat recovery system and a speed cap of 23 knots (42 kilometres/26 miles per hour) that reduces carbon dioxide emissions by up to 50 per cent compared with the Triple-E's predecessor.

Initially 20 Triple-Es are to be made by Maersk, with each vessel costing in the region of £123 million ($185 million).



Red lines indicate links between webpages in Asia, green for Europe, the Middle East and Africa, blue for North America, yellow for Latin America and white for unknown IP addresses

Every webpage is 19 clicks away

A physicist has argued that, despite its huge size, the internet is a very tight-knit network

A Hungarian physicist and his team have discovered that every page on the internet – that's over 14.8 billion and counting – is connected through a maximum of 19 links.

The research team, headed by Albert-László Barabási, went about working out the web's degree of separation number – ie its 'small world property' – by constructing a series of special algorithms that collected all the links on a webpage and then proceeded to track them to their various destinations repeatedly. Essentially what these algorithms revealed was that a user could theoretically get to any other page from the one they were currently on through, at the most, 19 mouse clicks.

Speaking on the publication of the results in *Philosophical Transactions Of The Royal Society*, Barabási said: "As the web began to grow in the Nineties, it was thought that it most probably had the properties of a random network. [But] two nodes are likely to be connected, even in such a very large and sparse scale-free network by a relatively short path of nodes – in the case of the web, the path length is about 19."

Barabási's team accounted the low figure to the emergence of 'super-hubs', such as Google and Facebook, which boast incredibly high levels of connectivity. This is why two small and seemingly disparate webpages can be linked, as these super-sites dramatically shorten the path between the two.

Barabási also warned that these super-hubs could potentially be a point of weakness if the internet came under attack, as they provide virtual structures that the rest of the web leans on.

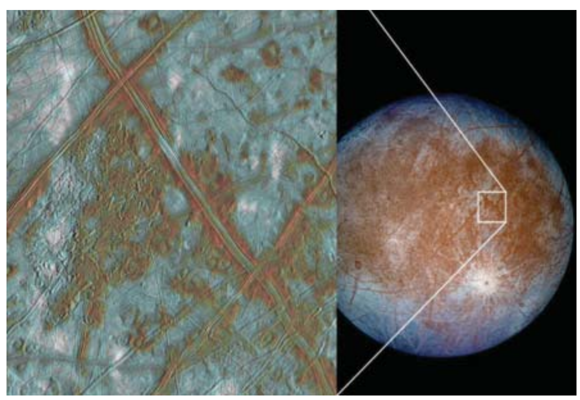
Europa is our best hope for finding life

NASA predicts the most likely place we'll find ET is not the Red Planet but an icy Jovian moon

Scientists at NASA have stated that Jupiter's moon Europa offers the best chance of finding life in our Solar System. The announcement flies in the face of decades of theorising Mars would be the best chance of finding evidence of life, with NASA highlighting the Red Planet's desert plains and harsh environment make it improbable life exists there.

In contrast, NASA scientists indicate that Europa's subsurface ocean, thin shelf of surface ice and presence of oxidants in the atmosphere make it a far more likely breeding ground for alien organisms.

Speaking on the announcement, Robert Pappalardo, a planetary scientist at the Jet Propulsion Laboratory (JPL) said: "Europa is the most promising in terms of habitability. It is the place we should be exploring now that we have a concept mission we think is the right one to get there for an affordable cost." NASA hopes an unmanned mission to Europa could launch as early as 2021, with the probe reaching the moon by 2027.



Europa's ice-laden surface and presence of oxidants mean there is a better chance of life existing there than on arid Mars

This day in history

21 March: How It Works issue 45 goes on sale, but what

537 CE
Goth uprising
Visigoth (or Goth) ruler King Vitiges attempts to assault Rome but is repulsed at the Praenestine Gate.

1152
Trouble at home
The marriage of King Louis VII of France and Queen Eleanor of Aquitaine is annulled (right).

1556
Bishop burns
The Archbishop of Canterbury, Thomas Cranmer, is burned at the stake (right).

1800
Papier papacy
Pius VII, driven out of Rome as a result of conflict, is crowned pope in Venice with a papier-mâché tiara.

1804
Live by the code
Emperor Napoleon introduces the Napoleonic Code as the basis for French civil law.

A passion for primates

TV zoologist Dr Charlotte Uhlenbroek tells us about her work with chimpanzees and reminds us how closely related we are to these fascinating creatures

What is it that draws you to chimps?
I have always been passionate about wildlife in general, but particularly animal behaviour – so I've always been [naturally drawn to] complex social systems.

Their basic social interactions are very familiar – is there anything significant at this level that separates us from them?
The evolution of symbolism and our communication was really what allowed us to take the path that we have. The fact that I can have this conversation with you – talk to you in depth about chimpanzee behaviour – it puts us in a whole different league.

Apart from watching adults, how else do juvenile chimps learn?
There's very little evidence of active teaching. A female with a baby while she's 'termiting', or using a tool to crack open nuts, will carry on with whatever she's doing. The little one will just start by playing around and picking up the termite stick. Then gradually it will start to try to do something a bit like what its [parent] is doing. You don't ever see a mother putting a tool into an infant's hand, for example, or showing it how to hold it properly.

If you took a baby chimp from the wild and placed it in captivity, would it be deprived of certain skills?
Yes. There's a critical age up to about seven or eight after which they will never try, no matter how much they're sitting around with other chimps doing something. It's as if that whole mimicry and experimental stage is over. It's always amazed me that if a chimp has come from a different community, where they don't use a particular tool, they just sort of sit around, while all the others, say, crack open nuts.

How unpredictable are chimpanzees?
There are patterns of behaviour that are fairly predictable, but having said that there are many, many days that took me by surprise. On one occasion I was sitting in the forest with a chimp called Prof: he just lay down under a tree and his foot was resting on a hollow log. He just tapped his foot on the log and it made quite a resonant sound. Then he tapped his foot again, repeatedly over the next five or so minutes. I thought that was extraordinary.

So chimps drum on trees?
They drum on buttress [roots], but I've never seen that kind of experimental tapping. It was almost as if I was witnessing his discovery of music – the earliest seeds of that appreciation of a sound for its own sake. On another occasion there was a young chimp who was crossing a stream and he stopped halfway across. He put his hand palm up into the water and he was just lifting the water up and letting it fall through his fingers.

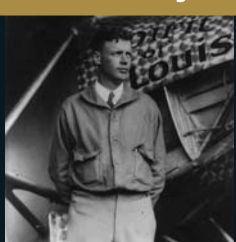
"There are patterns of behaviour that are fairly predictable, but there are many, many days that took me by surprise"

He seemed to be mesmerised by the light and patterns, and the water itself… There are always surprises that make you think they are interested in the world around them beyond just finding food and keeping dry, etc.

To learn more about the lives of chimps, have a look at our feature starting on page 40.

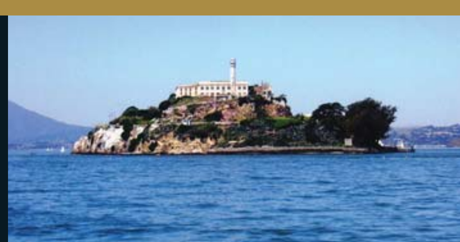
else happened on this day in history?

1928
High flyer
US aviator Charles Lindbergh (right) is presented with the Medal of Honor for the first solo transatlantic flight.



1945
Liberation
During the Second World War British troops liberate the city of Mandalay, Burma.

1963
Last lockdown
The federal prison on Alcatraz Island (right) in San Francisco Bay, CA, closes its doors.



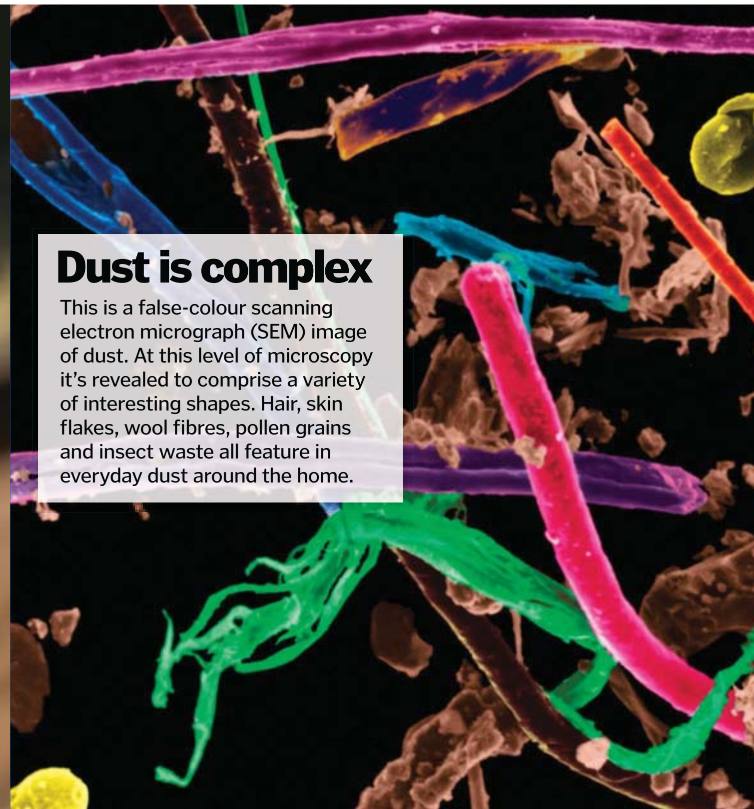
1999
A lot of hot air
Bertrand Piccard and Brian Jones are the first to circumnavigate Earth in a hot-air balloon.

10 COOL THINGS WE LEARNED THIS MONTH

FACTS YOU ALL SHOULD KNOW

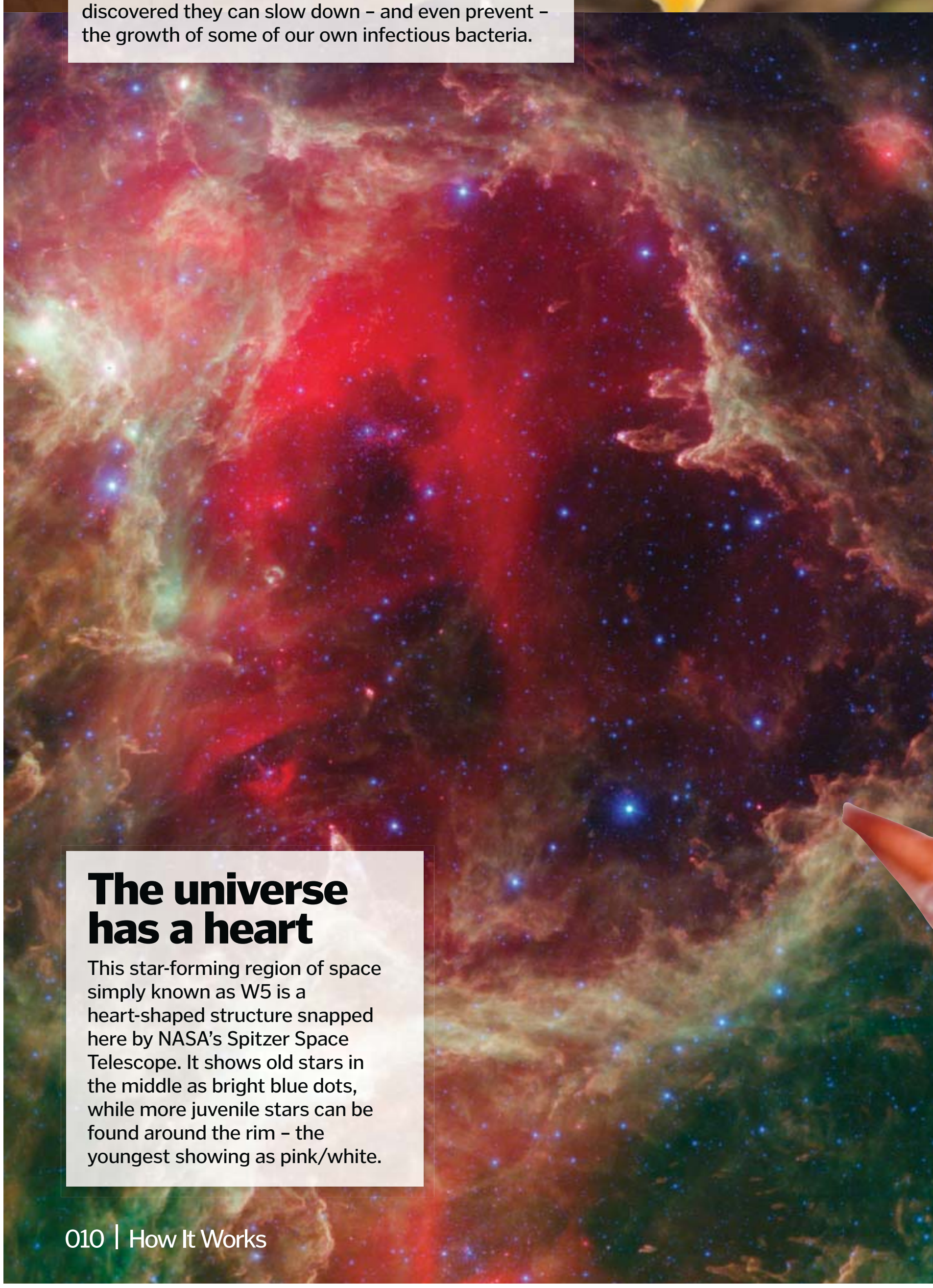
Trout are antibiotic

The mucus, or slime, found on the scales of certain fish like the trout has antibacterial properties that could potentially be harnessed as an alternative to antibiotics. Trout use their mucus to protect themselves from bacteria in rivers and scientists have discovered they can slow down – and even prevent – the growth of some of our own infectious bacteria.



Dust is complex

This is a false-colour scanning electron micrograph (SEM) image of dust. At this level of microscopy it's revealed to comprise a variety of interesting shapes. Hair, skin flakes, wool fibres, pollen grains and insect waste all feature in everyday dust around the home.



The universe has a heart

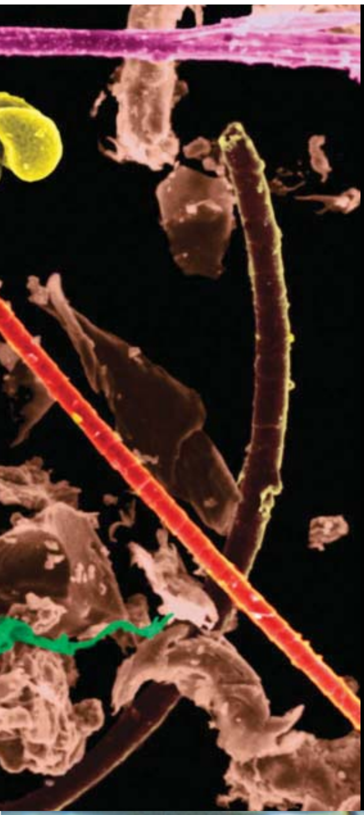
This star-forming region of space simply known as W5 is a heart-shaped structure snapped here by NASA's Spitzer Space Telescope. It shows old stars in the middle as bright blue dots, while more juvenile stars can be found around the rim – the youngest showing as pink/white.

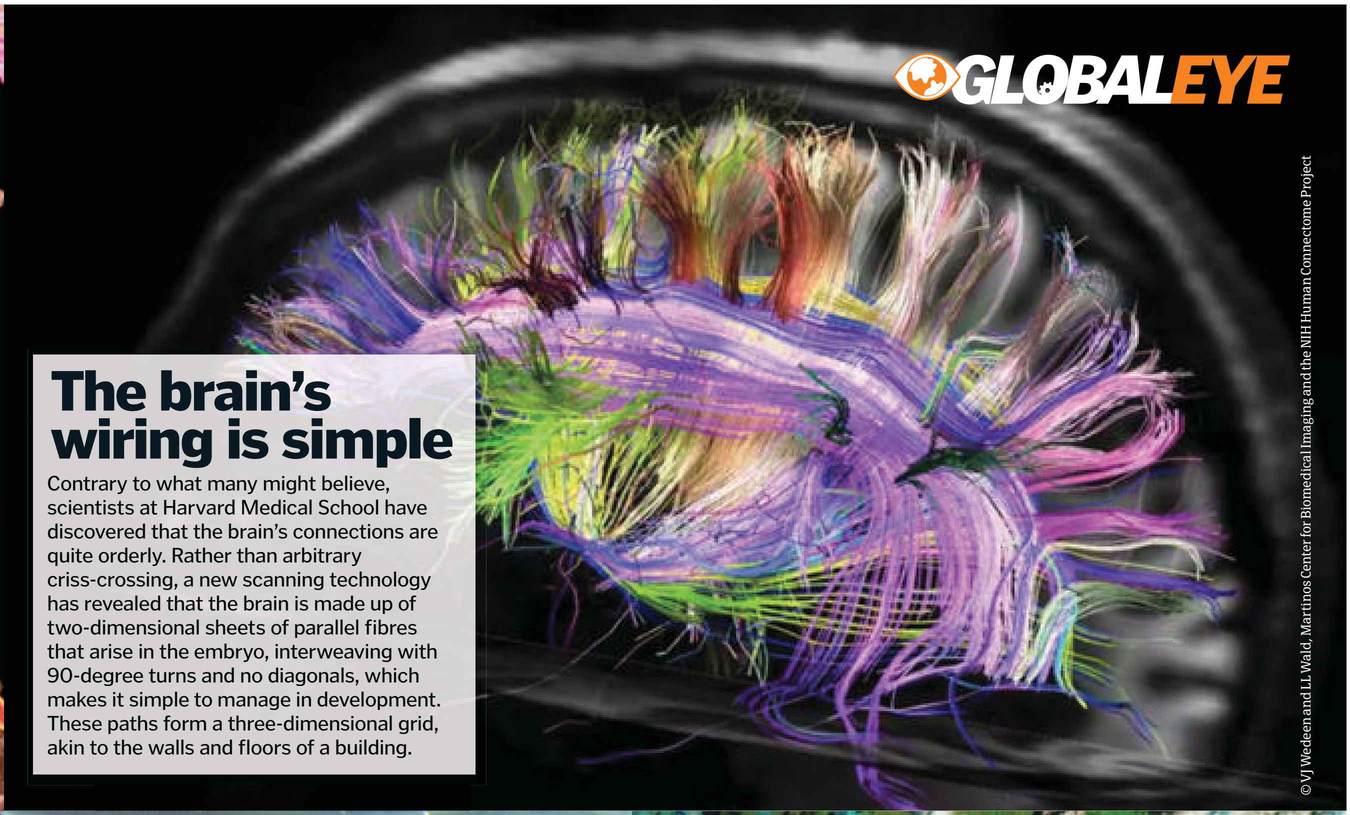
Black holes can stretch general relativity

At the heart of galaxy NGC 1365 is a supermassive black hole with a mass of about 2 million times our own Sun moving at a rate of spin that approaches the boundaries of Einstein's theory of general relativity. By tracing matter and X-rays that are warped as they near the black hole, its origins and the history of its host galaxy can be determined from 60 million light years away on Earth.

Bacteria feed cockroaches

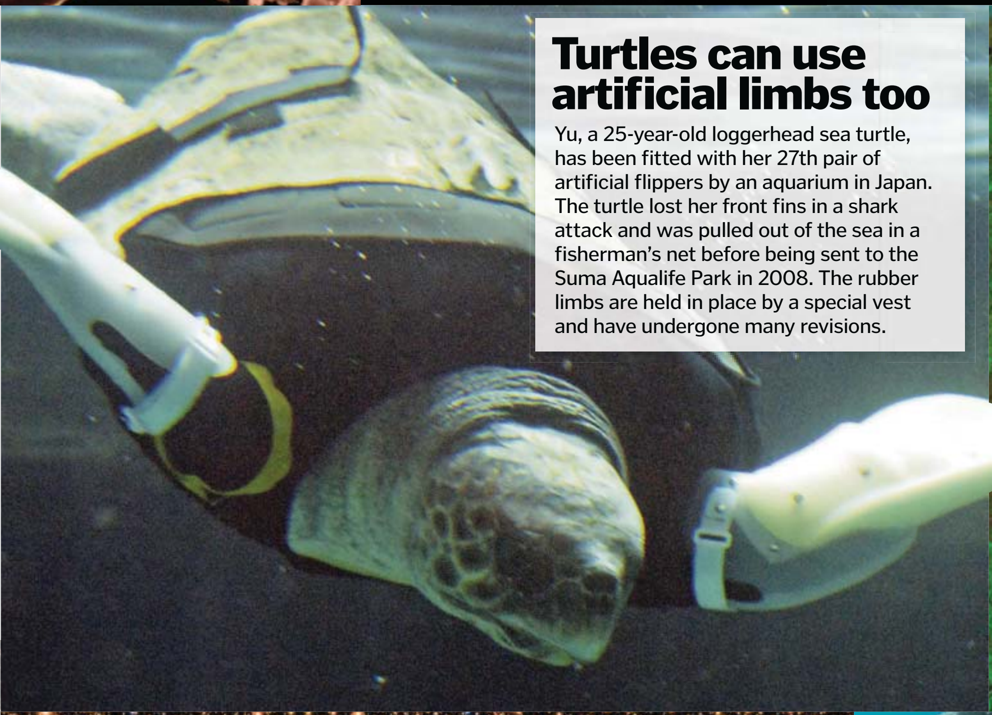
One reason cockroaches have thrived for millions of years is the symbiotic bacteroides in their bodies. These rod-shaped bacteria live in the comfort of the cockroach's fatty tissues and manufacture all the vitamins and amino acids the bug requires. This means that not only can the cockroach eat almost anything, but it can also go for weeks without food.





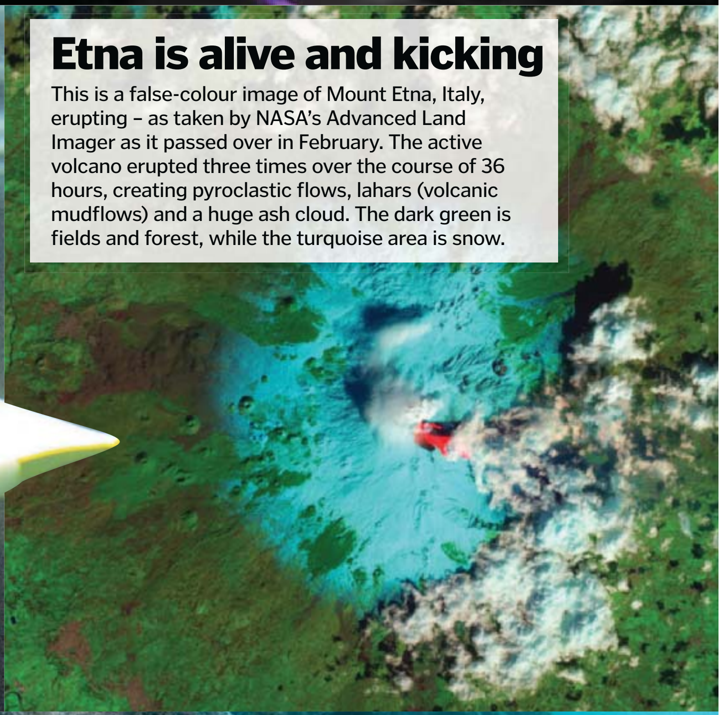
The brain's wiring is simple

Contrary to what many might believe, scientists at Harvard Medical School have discovered that the brain's connections are quite orderly. Rather than arbitrary criss-crossing, a new scanning technology has revealed that the brain is made up of two-dimensional sheets of parallel fibres that arise in the embryo, interweaving with 90-degree turns and no diagonals, which makes it simple to manage in development. These paths form a three-dimensional grid, akin to the walls and floors of a building.



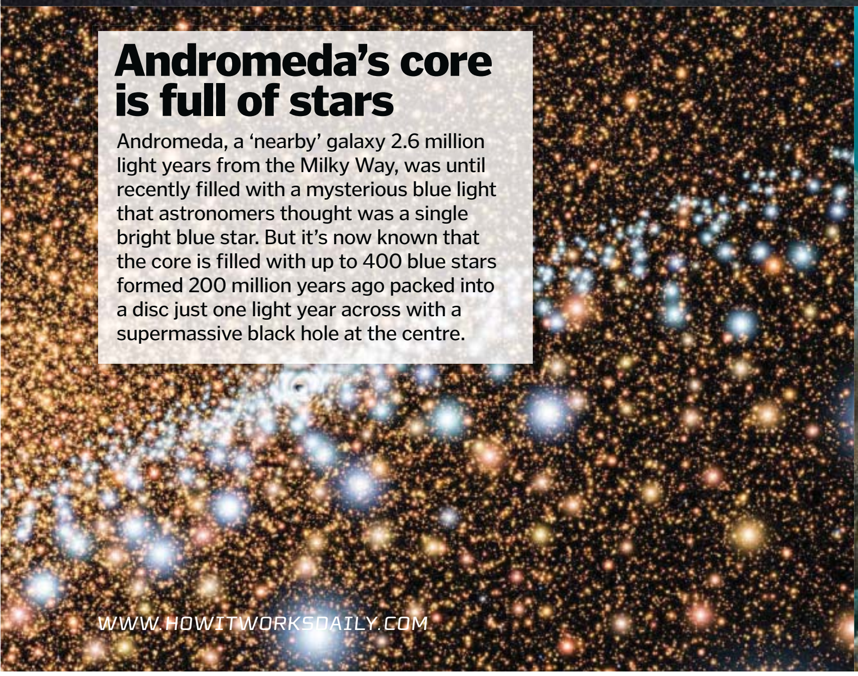
Turtles can use artificial limbs too

Yu, a 25-year-old loggerhead sea turtle, has been fitted with her 27th pair of artificial flippers by an aquarium in Japan. The turtle lost her front fins in a shark attack and was pulled out of the sea in a fisherman's net before being sent to the Suma Aqualife Park in 2008. The rubber limbs are held in place by a special vest and have undergone many revisions.



Etna is alive and kicking

This is a false-colour image of Mount Etna, Italy, erupting – as taken by NASA's Advanced Land Imager as it passed over in February. The active volcano erupted three times over the course of 36 hours, creating pyroclastic flows, lahars (volcanic mudflows) and a huge ash cloud. The dark green is fields and forest, while the turquoise area is snow.



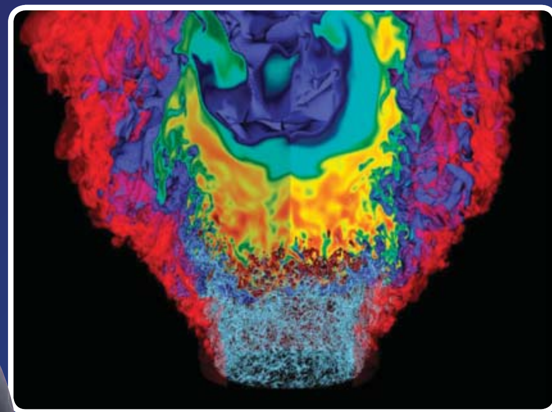
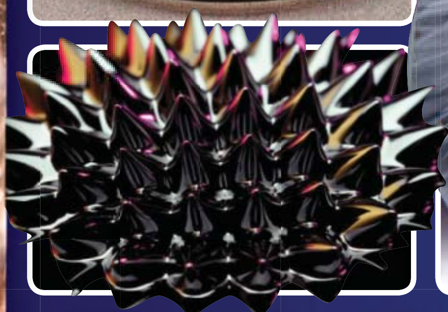
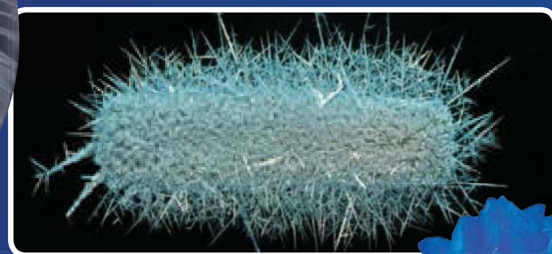
Andromeda's core is full of stars

Andromeda, a 'nearby' galaxy 2.6 million light years from the Milky Way, was until recently filled with a mysterious blue light that astronomers thought was a single bright blue star. But it's now known that the core is filled with up to 400 blue stars formed 200 million years ago packed into a disc just one light year across with a supermassive black hole at the centre.

Some fish switch sex

The ribbon eel is a saltwater fish native to both the Indian and Pacific oceans. They're born black and male but, as they mature, they turn female and develop blue and yellow skin. Known as protandry, this rare ability to switch from male to female is also a trait of clownfish.




AMAZING CHEMISTRY

Ten of Earth's most awe-inspiring chemical and physical reactions at an atomic level

Chemistry is a fascinating subject. The way atoms behave determines everything from the food we eat and the clothes we wear, to our genetic makeup and how we feel. The beautiful simplicity of the periodic table describes just 118 elements that form every known material – 98 if you discount those that can only exist in a laboratory. These elements react in a variety of ways, forming hundreds of millions of compounds – two or more elements bonded together – giving us the diversity of materials that make up our world.

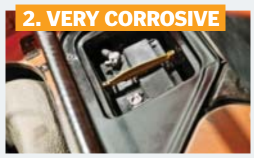
Some reactions are physical, not chemical, and the way to tell is whether or not there has been a change in the chemical formula. Melting ice is a physical change because water is the same substance as ice, just in a different state of matter. Burning coal, on the other hand, is a chemical change, as coal and oxygen combine to make carbon monoxide – a chemically unique material. A chemical reaction drives the change of one substance into another and the reactions are generally identified by colour changes or a release of energy – often in the form of heat, light and sound: the ingredients of an explosion.

It is impossible to cover the astonishing range of chemical reactions that happen in our universe in one article, so we've picked ten standout ones which have dramatic results.

1. CORROSIVE

Iron oxide (rust)
Given enough time, iron either left in water, or in contact with water vapour in air, will rust – forming iron oxide.

2. VERY CORROSIVE



Battery acid
Due to the corrosive nature of sulphuric acid – commonly found in car batteries – the terminals on the battery tend to corrode after a few years.

3. MOST CORROSIVE

Hydrofluoric acid
Hydrofluoric acid is a relatively weak acid, yet it corrodes most metals and can even dissolve glass, so it's used in glass etching.

DID YOU KNOW? *A catalyst is a substance added to speed up chemical reactions, while inhibitors slow them down*

Reaction types

Distinguishing between physical and chemical reactions is one thing, yet chemists have identified five common ways that chemical changes can be broken down further. These are: synthesis, decomposition, single replacement, double replacement and oxidation/reduction (redox).

Some reactions can exhibit characteristics of more than one of these labels – as all chemical reactions are caused by the sharing, gaining or losing of electrons. However it's helpful to categorise reactions by the distinct ways in which they behave.

Synthesis

A synthesis reaction occurs when two or more chemical elements or compounds react together to make a more complicated compound. For example – burning hydrogen (H_2) and oxygen (O_2) gas forms the more complex water molecule (H_2O).

A + B → A-B

Decomposition

Decomposition is the breaking down of two or more complex molecules into simpler ones. Passing an electric current through water (H_2O), results in the 'decomposition' of the water molecule into its basic elements: hydrogen (H_2) gas and oxygen (O_2) gas.

A-B → A + B

Single replacement

When one element is bumped by another in a compound, it's a single replacement reaction. Reactions with metals and acids often fall into this group. Magnesium (Mg) and hydrochloric acid (HCl) react to form magnesium chloride ($MgCl_2$) and hydrogen (H_2), where Mg replaces H_2.

A-B + C → A-C + B

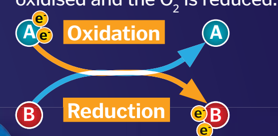
Double replacement

In some cases, compounds 'swap' their components – this is called a double replacement reaction. For example, hydrochloric acid (HCl) and sodium hydroxide (NaOH) react together, producing sodium chloride (NaCl) and water (H_2O). In this reaction, the hydrogen and sodium atoms have switched places.

A-B + C-D → A-C + B-D

Redox

Oxidation and reduction (ie redox reactions) describe a chemical change where electrons are transferred. You can't have oxidation (loss of electrons) without reduction (gain of electrons). When H_2 burns with O_2, the H_2 becomes oxidised and the O_2 is reduced.



THE METAL MELTER

Thermite reaction

Deadliness: ☠☠☠☠
Ingredients: Aluminium (Al); iron oxide (Fe_2O_3)
Core process: Single replacement

✗ In nature ✓ In lab ✗ At home ✗ Toxic

Thermite is a very cool – well, hot – reaction that consists of metal powder and a metal oxide (most often aluminium and iron oxide); the latter more commonly known as rust. The characteristics of thermite reactions are not so much explosive; rather it's their ability to heat very small areas to incredibly high temperatures where they excel. You don't think of metals as burning very easily, but in the right conditions – and very high ignition temperatures – they can.

Thermite reactions are used for welding train tracks together and temperatures as high as 2,500 degrees Celsius (4,532 degrees Fahrenheit) can be reached. Due to the blazing heat, products of thermite reactions are liquid, making them perfect for welding. As thermite reactions have their own supply of oxygen from the metal oxide they can work even in the absence of air, such as underwater and in space.

Aluminium and iron oxide are heated, often with magnesium ribbon as a fuse, and oxygen from the iron oxide breaks its bond to combine with the aluminium to form aluminium oxide and iron. Special face masks with UV protection must be worn when welding due to the intense radiation.

THE CRYSTALLISER

Copper sulphate crystals

Deadliness: ☠
Ingredients: Copper sulphate pentahydrate ($CuSO_4$*$5H_2O$); water (H_2O)
Core process: Crystallisation

✓ In nature ✓ In lab ✓ At home* ✓ Toxic

*(But take care as copper sulphate can be a mild irritant)

What it lacks in explosive power, copper sulphate more than makes up for in its looks – creating brilliant blue crystals when its hydrated form is dissolved in hot water. Copper sulphate is a type of salt, and is most commonly encountered as a powder – copper sulphate pentahydrate ($CuSO_4$*$5H_2O$). This is a way of expressing five water molecules are attached to the copper sulphate molecule; it is hydrated. For blue crystals to form, copper sulphate pentahydrate is added to hot water up until the point where no more can dissolve. This is referred to as a saturated solution, and a hotter solution can dissolve more copper sulphate than a colder one. When the solution starts to cool, some of the copper sulphate can no longer exist in a dissolved state, so the molecules gather in an organised repeating pattern, forming crystals. This is an example of a physical change since the material is altering its structure rather than its makeup. Suspending a nylon wire in the solution creates a surface for the crystals to latch on to, encouraging growth. Eventually the water evaporates, but copper sulphate can't so it's forced into an ever-smaller space. The molecules of copper sulphate continue crystallising until no water is left.

"The light from a pure hydrogen and oxygen reaction is mainly ultraviolet, making the flame almost invisible"

Top five deadliest reactions

1 Hydrochloric acid and most things…
Hydrochloric acid (HCl) is an extremely strong acid. HCl reacts with most things – especially bases – and can corrode metal, cause chemical burns and even release flammable hydrogen.

2 Acid rain
When sulphur dioxide is released into the air, it rises up and reacts with hydrogen peroxide which is found in some clouds. Sulphuric acid – a product of the reaction – falls back down to Earth and can have devastating effects on flora, fauna and buildings/statues, etc.

3 Nitroglycerine and heat
Nitroglycerin is one of the most explosive substances there is. The oily liquid is so sensitive that the slightest jolt or increase in heat can trigger a massive explosion.

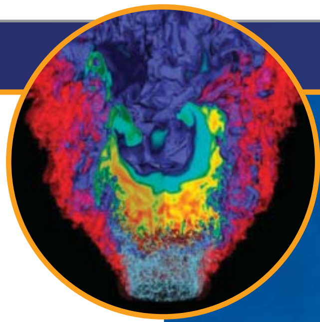
4 Bleach and ammonia
When ammonia and bleach are mixed, the bleach decomposes to form hydrochloric acid. Ammonia and chlorine gas react to form a deadly vapour: chloramine.

5 Mustard gas
The volatile combination of sulphur dichloride and ethylene reacts to form a cyclic sulphonium ion. This reacts with parts of DNA to prevent cells from replicating, leading to tissue necrosis.

THE FIRESTARTER

Burning hydrogen

Deadliness: ☠☠☠
Ingredients: Hydrogen (H_2); oxygen (O_2)
Core process: Redox
☒ In nature ☑ In lab ☒ At home ☒ Toxic



Hydrogen (H_2) is the lightest, most abundant element in the universe, yet it's also one of the most flammable. Hydrogen is quick to burn in the presence of oxygen (O_2) and can be very explosive. Used as the primary fuel for combustion when launching space shuttles, this is seriously powerful stuff. When hydrogen burns, large quantities of heat and light are given off. The light emitted from a pure hydrogen and oxygen reaction is mainly ultraviolet, making the flame almost invisible – however, in reality, there are often other materials present, creating a visible flame. Water is the waste product of hydrogen combustion, since oxygen and hydrogen are the two ingredients in water. Combustion of liquid hydrogen and oxygen is used to launch rockets – hence it is water vapour, not smoke, which you see coming out of the exhaust during the takeoff.

Scientists are now working on using hydrogen combustion to power cars and other machines. The difficulty is the large amount of initial energy needed to get the reaction going. It requires far more energy to get started than, say, traditional fossil fuels.

Hydrogen is rarely found on Earth in its pure form, because it prefers to join with other elements – and of course a great deal exists as water.

THE BOMB DECOY

Magnesium and Teflon

Deadliness: ☠☠☠
Ingredients: Magnesium (Mg); Teflon ($[C_2F_4]n$)
Core process: Redox
☒ In nature ☑ In lab ☒ At home ☒ Toxic

Magnesium (Mg) is a highly reactive element which burns at a staggering 3,100 degrees Celsius (5,612 degrees Fahrenheit), giving off an intense white light. In addition to visible light, magnesium emits infrared (IR) when burned, making it perfect for use in military countermeasures such as decoy flares. Like all things, magnesium needs to be in the presence of an oxidiser when it burns – a material which takes electrons from the fuel allowing the reaction to occur. Flares are made of Teflon ($[C_2F_4]n$) and magnesium, and it's the fluorine in Teflon that oxidises magnesium. Fluorine is a stronger oxidiser than oxygen, as it wants to accept electrons more than oxygen, allowing for a higher temperature of combustion. Heat-seeking missiles lock on to infrared light given off by engines in aircraft, but magnesium decoy flares throw out far more IR light than aeroplane engines, effectively confusing the missiles' heat-seeking guidance systems and hopefully deterring the weapon from its target.

A magnesium fire cannot be extinguished with water, since the magnesium reacts with water to produce hydrogen gas – which if anything will only intensify the fire. Instead, dry sand is generally used to stop the reaction. Other uses of magnesium have been as an illumination source in flash photography and in fireworks.

THE SOLIDIFIER

Sodium acetate supersaturation

Deadliness: ☠ **Ingredients:** Sodium acetate ($NaC_2H_3O_2$); water (H_2O)
Core process: Crystallisation

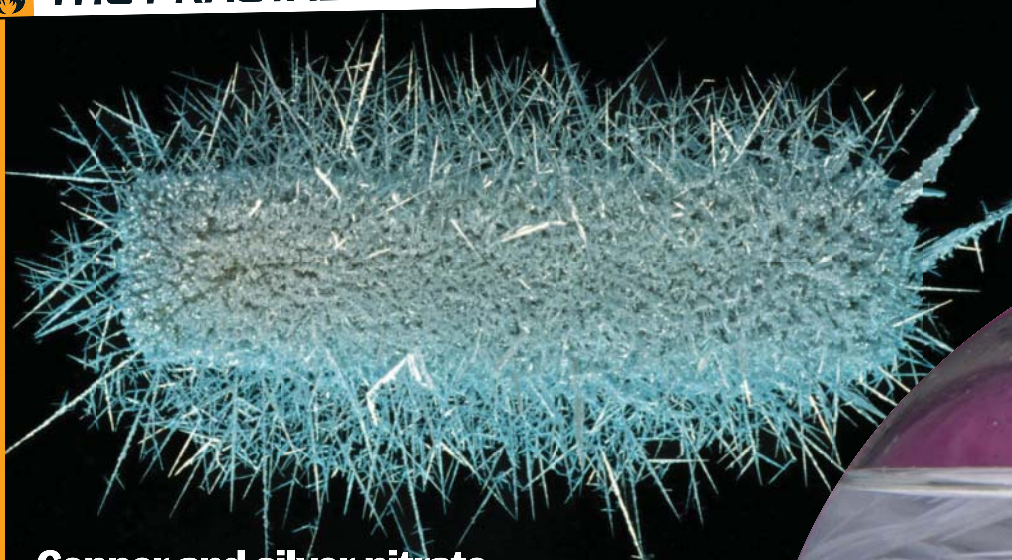
✗ In nature ✗ In lab ✓ At home* ✗ Toxic *(Heat is given off but not enough to cause burns)

Sodium acetate ($NaC_2H_3O_2$) heated in water then cooled has the unusual property of crystallising into a solid when it is disturbed. It can be poured out of a beaker as a liquid and, upon hitting a surface, becomes a solid that is hot to touch – hence its other name, hot ice. Sodium acetate is a salt which dissolves in water. Heating – to around 100 degrees Celsius (212 degrees Fahrenheit) – then cooling a mixture of the two allows more sodium acetate to dissolve to form a supersaturated solution. The solution exists in a metastable state, analogous to a ball perched at the top of a hill, where the slightest nudge will make it roll down.

The trigger can be pouring the solution out of the container, or adding a seed crystal, causing the dissolved sodium acetate to come out of the solution and return to a solid. In our analogy this is like the ball rolling down the hill until it reaches flat ground and a lower energy state.

Along the way, the solid sodium acetate absorbs three molecules of water, becoming sodium acetate trihydrate ($NaC_2H_3O_2$*$3H_2O$). These water molecules are not chemically bonded to the sodium acetate, representing a physical change. The process is exothermic (ie it releases heat) and, as a result, it's often used in hand warmers.

THE FRACTAL MAKER



Copper and silver nitrate

Deadliness: ☠
Ingredients: Silver nitrate ($AgNO_3$); copper (Cu); water (H_2O)
Core process: Single replacement

✗ In nature ✓ In lab ✗ At home ✓ Toxic

Mixing silver nitrate and copper is one of the most famous chemistry experiments, with it starring in many a school science lesson around the globe. The experiment involves introducing copper – typically a copper wire – to a silver nitrate/water solution and suspending it there for a couple of hours.

The combining of both triggers a single replacement reaction, where copper is changed from its elemental form (Cu) to its blue aqueous ion form (Cu_2+ [aq]), while the silver ions (Ag+ [aq]) in the silver nitrate solution will be changed into their elemental metallic form (Ag) and deposited onto the wire. These silver deposits continue to grow off the copper in a series of fractal-like crystals until all reactable copper in the solution is exhausted, leaving the end products of silver and copper nitrate.

The reason this replacement reaction occurs is that the atoms in the copper are oxidised when introduced to the silver nitrate solution, losing electrons and forming copper ions, while the silver ions in the nitrate solution are reduced (ie they gain electrons) into elemental silver.

What's really cool is that once the silver crystals have grown they can be removed from the copper, dried off and then displayed as funky pieces of fractal art.

"Even oxygen in the air is enough to cause potassium to spontaneously combust"

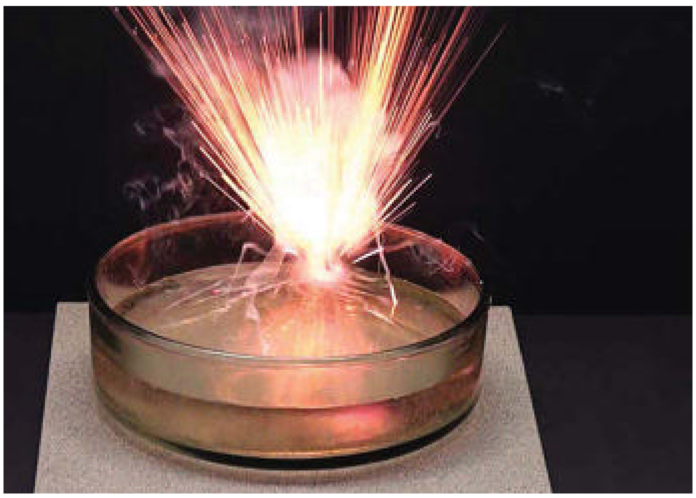
THE WITCH'S POTION

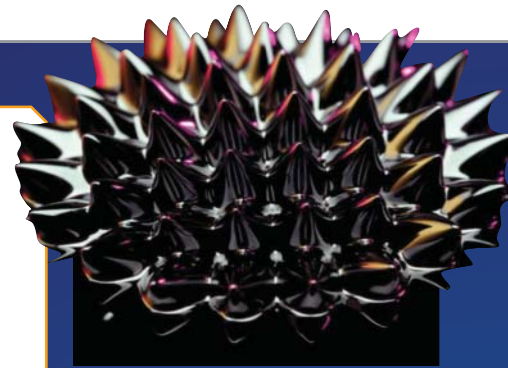
Potassium and water

Deadliness: ☠☠☠
Ingredients: Potassium (K); water (H_2O)
Core process: Redox

✗ In nature ✓ In lab ✗ At home ✗ Toxic

Put a lump of potassium in a dish of water and it will give off a pinkish light, get very hot and skim across the surface at speed. A favourite experiment of many science classrooms, potassium is a highly reactive metal that reacts violently in the presence of oxygen and water. It forms potassium hydroxide (KOH) and hydrogen gas (H_2). Potassium atoms have 19 electrons – one of which is alone in an outer shell. This makes potassium very keen to lose an electron so it has a complete outer shell and is more stable. When the reaction begins, enough heat is given off to ignite the hydrogen gas, which then reacts with oxygen to produce water. Potassium is so reactive that it must be stored in kerosene, so as not to come into contact with water vapour in the air. Even oxygen in the air is enough to cause potassium to spontaneously combust! Because potassium is so reactive, it's not found in its elemental form, but is common as a compound.





Ferrofluid

This experiment combines physics and chemistry to produce an awesome effect. Ferromagnetic fluid is a liquid that undergoes a radical change when introduced to a magnetic field, turning from a puddle into a spiked dome. The fluid does this due to its composition, which is a mix of nanoscale ferromagnetic particles (like iron) and a carrier fluid. The particles are coated with a surfactant – a compound that lowers a liquid's surface tension – ensuring an even distribution of particles. When a magnetic field is introduced – usually a strong magnet positioned beneath it – the particles realign to the magnetic field lines. Contained as they are, the particles cause the liquid to act like a solid.

THE SCREAMING JELLY BABY

Potassium chlorate and most things (in this case Jelly Babies)

Deadliness: ☠☠☠
Ingredients: Potassium chlorate ($KClO_3$); Jelly Babies (glucose syrup, sugar, water, gelatine and flavourings)
Core process: Redox

✗ In nature ✓ In lab ✗ At home ✓ Toxic

Watching a Jelly Baby meet its demise at the hands of potassium chlorate is a spectacular affair. There's an abundance of energy inside Jelly Babies stored as sugar, released in intense flames and a piercing scream when potassium chlorate is added to the mix.

Potassium chlorate is a powerful oxidiser, taking its form as a white powder and commonly used in fireworks and explosives. The 'ate' part of chlorate describes the oxygen atoms attached to the chlorine atom, and the chemical formula is $KClO_3$. Chlorate-based oxides are more efficient oxidisers than those in gunpowder and potassium chlorate needs to be handled very carefully due to its unpredictable ability to spontaneously ignite.

The reaction happens when a small amount of potassium chlorate is placed in a test tube and heated until it becomes a clear liquid. Needless to say, safety screens and goggles are a must. The Jelly Baby is placed with tongs into the tube and instantly produces lively flames, intense screaming and plenty of smoke. The reaction can last up to 20 seconds and gives off noxious fumes so ventilation is also needed.

Flame test

The flame test is one of the simplest yet coolest experiments in the lab. By introducing certain elements – generally metals – to a Bunsen burner, you can determine their composition by analysing the emission spectrum. This works as the heat excites the material's ions, so they emit visible light. For example, if you have a chunk of unknown metal, by introducing it to a calibrated burner (one that is not contaminated) and evaluating the colour(s) of the flame, you can determine what the substance is made of. Copper (Cu) emits a blue-green flame, lithium (Li) a bright red one, while the image above shows the orange/crimson flame generated by strontium (Sr).

Which is the strongest acid?

A Citric acid **B** Stomach acid **C** Bleach

Answer:
Stomach acid is stronger than citric acid and bleach – the latter isn't even an acid. Stomach acid measures between 1.5 and 3.5 on the pH scale and contains potent hydrochloric acid. It serves to kill any harmful microbes and bacteria we consume.

DID YOU KNOW? *Superacids are acids with an acidity greater than that of 100 per cent sulphuric acid*

THE BARKING DOG

Carbon disulphide and nitrous oxide

Deadliness: ☠☠☠
Ingredients: Carbon disulphide (CS_2); nitrous oxide (N_2O)
Core processes: Decomposition; redox

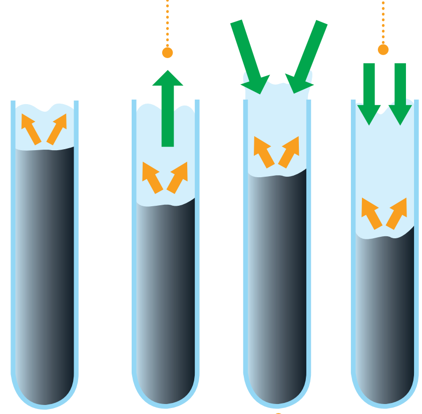
✓ In nature (the reactants) ✓ In lab ✗ At home ✓ Toxic

The barking dog reaction is a consequence of igniting carbon disulphide (CS_2) mixed with nitrous oxide (N_2O) – the latter is better known as laughing gas. The reaction generates a bright flash of blueish-purple light and heat, and, more bizarrely, a sound like a dog barking.

Nitrous oxide gas is the source of oxygen – ie the oxidiser – needed to burn the colourless liquid fuel, carbon disulphide. When the reaction takes place in a confined space – such as a long tube – some energy is converted to form the rapid but loud barking noise, due to a fluctuation of pressure. This is an example of a reaction which makes elements from compounds: in this case a yellow coating of sulphur and nitrogen gas are the elements left in its wake.

Carbon disulphide is found in nature as a product of the metabolic processes in plants, and also volcanic eruptions. Nitrous oxide also forms naturally from some species of bacteria, plus through industry and agriculture, and it depletes ozone in the stratosphere.

Used in the distant past as a method of flash photography, the flash it produces is so bright that many people in the photographs would often appear startled. The pervasive smell that sulphur compounds are capable of probably didn't make it that popular either.



1. Energy release
Nitrous oxide reacts with the carbon disulphide releasing energy as heat, expanding the gases.

2. Expansion
As the gases expand, those near the top are forced out of the test tube due to pressure.

3. Differential
The expelled gases lead to a pressure drop within the tube, creating a vacuum-like effect.

4. Bark
As the gases rush back into the tube to balance the pressure, a repeated 'barking' noise is made.

THE CANDY ROCKET

Potassium nitrate and sugar

Deadliness: ☠☠
Ingredients: Potassium nitrate (KNO_3); sucrose ($C_{12}H_{22}O_{11}$)
Core process: Redox

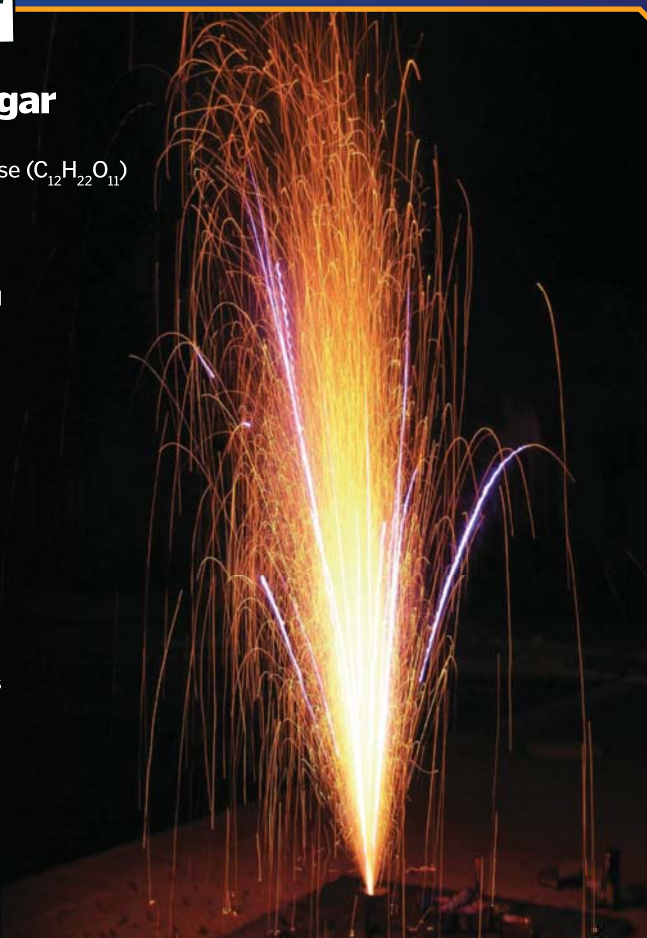
✗ In nature ✓ In lab ✗ At home ✓ Toxic

There's something strangely satisfying about witnessing the volatile display of smoke, colour and fire given off by the mixture of potassium nitrate, sugar and heat. The amount of fire varies, but there is always an abundance of smoke. You have most likely seen this reaction at a firework display, or from the smoke stunt planes deploy where coloured dyes are often added for effect.

Potassium nitrate (KNO_3)– aka saltpetre – is an essential in any pyrotechnics cookbook; it's one of the main ingredients in gunpowder, for example. Potassium nitrate works as an oxidiser, giving off oxygen and promoting the burning of fuel.

As seen in the 'Screaming Jelly Baby', sugar is an extremely effective fuel; it contains energy that 'burns' in our bodies and converts to useful energy we use to perform any physical activity. When heat is applied to saltpetre and sugar, the saltpetre loses an oxygen atom – transitioning from KNO_3 to KNO_2 and oxidising the sugar. The sugar burns, releasing smoke which rapidly expands and can generate enough thrust to lift a small rocket.

Interestingly there's a programme called Sugar Shot to Space that aims – as you would probably guess – to launch a rocket powered by sugar propellant alone beyond Earth's atmosphere.



Useful reactions

1 Photosynthesis
The chemical process of turning sunlight into energy is vital to life, allowing plants to grow and release their waste product: oxygen. As well as regulating the levels of oxygen in the atmosphere, photosynthesis is the source of energy for most organisms.

2 Baking bread
In times when other food sources were scarce, the discovery of heating flour mixed with water combined with yeast fermentation was a breakthrough. Yeast ferments sugars and carbohydrates giving off CO_2.

3 Extraction of metals
One of the world's largest industries, extracting metals from their ores using chemical reactions is hugely important, as most metals are mixed with impurities in their natural state.

4 Galvanising steel
From lampposts to buildings steel is everywhere around us and protecting these things from rust is vital. Dipping steel in a bath of zinc causes a chemical reaction which adheres a coating of zinc to the steel to protect it from water vapour.

5 DNA production
The essential 'code' for all known life, DNA is a molecule with our genetic instructions in the form of nucleotides – a set of long polymers made of sugars and phosphates. Chemical reactions allow the DNA to form, replicate and interact with proteins to make us who we are.

> "The most common causes of hyperventilation are psychological – a result of a stressful situation"

Hyperventilation

What can bring on this short-of-breath feeling and is a paper bag really the best treatment?

Hyperventilation is the excessive ventilation of the lungs: in other words, rapid and often shallow breathing beyond what the body requires to maintain normal gas quantities in the bloodstream.

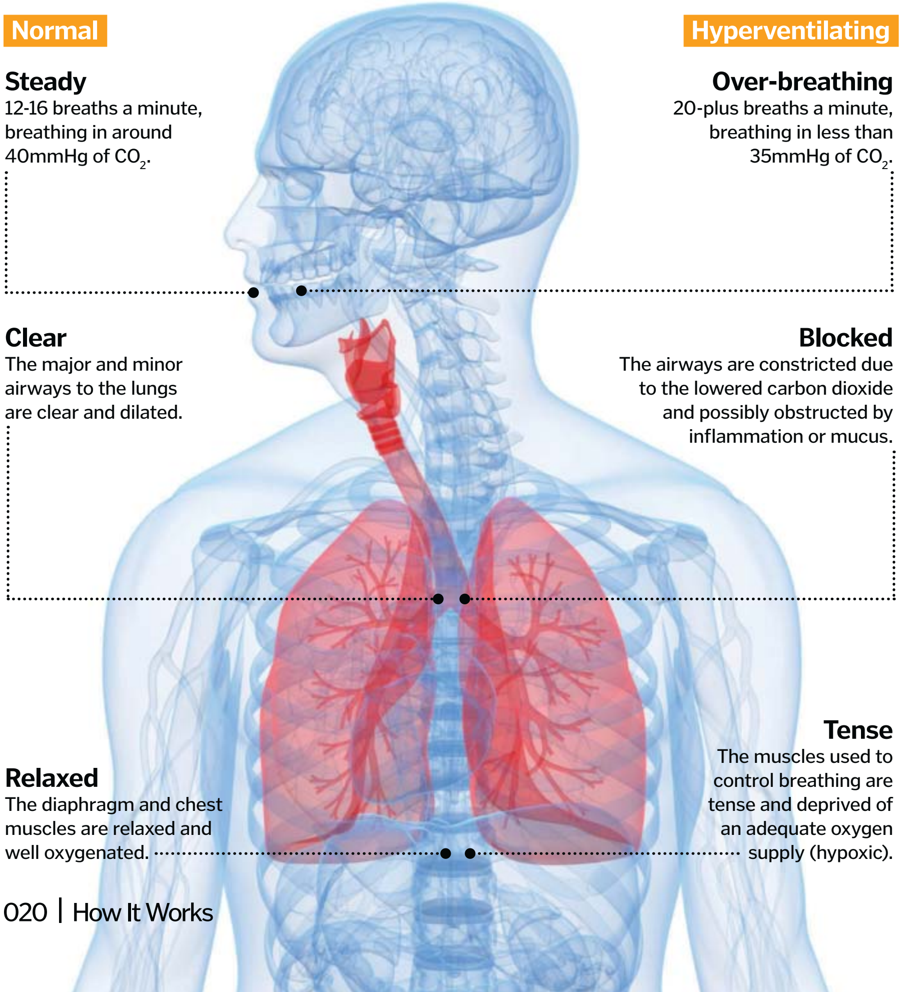
There are a number of reasons why a person might hyperventilate and those can generally be divided into two camps: psychological and physiological conditions. As a symptom of more serious ailments it can result from renal (kidney) failure, pulmonary oedema (fluid in the lungs), drug overdose, a fever and, more frequently, asthma. The most common causes of hyperventilation, however, are psychological – a result of a stressful situation or a panic attack.

Contrary to popular belief, the effect of this kind of breathing isn't to increase oxygen intake, but to lower the volume of carbon dioxide in the blood by exhaling more than the amount produced by the body. When carbon dioxide levels are too low, blood vessels in the brain constrict causing lightheadedness and – in extreme cases – fainting. This can only serve to increase a person's anxiety and exacerbate the hyperventilation.

The well-known treatment of breathing into a paper bag (neither advised nor taught) was invented by a US army medic in 1951. Although this method – known as rebreathing – often works, today's medical experts say it is dangerous and should be avoided.

What happens when we hyperventilate?

We look at the main changes in the body when we take in too much air



Atmospheric temperature

Why does the air temperature radically fluctuate with altitude?

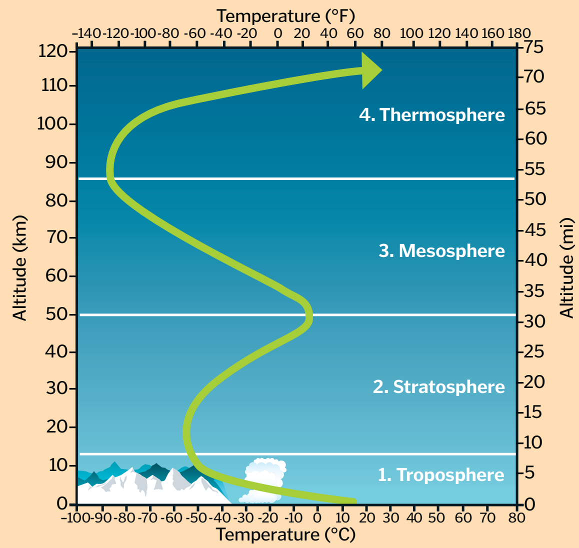
We're taught hot air rises and we can see this in practice when a hot-air balloon climbs into the sky. So why does the air temperature plummet at greater altitudes? There are a number of variables that affect atmospheric temperature and the best known is solar radiation. This doesn't heat the air directly though. Lapse rate describes the general decrease in atmospheric temperature with height, which occurs because the atmosphere is heated by conduction with the Earth's surface. The farther you move from the surface, the less dense the air is and the more it struggles to retain heat. But the temperature doesn't follow a unidirectional gradient. For example, while at 80 kilometres (50 miles) it can be -100 degrees Celsius (-148 degrees Fahrenheit), the air is much warmer at 115 kilometres (70 miles) due to ionising radiation.

Atmosphere layer by layer

Take a trip through Earth's atmosphere to see the location of the hottest and coldest areas

1. Troposphere
This extends up to about 12km (7mi) and is where our weather occurs. Temperature drops about 6.5°C per kilometre here.

2. Stratosphere
The bulk of the ozone layer is here and the temperature increases to just below freezing near the stratopause.



3. Mesosphere
Between 50km (31mi) and 100km (62mi) temperatures plummet because of CO_2 cooling and low solar heating.

4. Thermosphere
Stretching up to 600km (373mi) from the Earth's surface air here can reach 1,800°C (3,272°F) but is too thin for us to feel it.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"Embryonic stem cells transform the embryo from a tiny ball of unspecialised cells into a baby"

Secrets of stem cells

Meet the miracle cells that might just revolutionise medicine

Stem cells are cells with the unique potential to become multiple different types of cell within the body.

Most of your cells are equipped to accomplish a specific job, whether carrying oxygen in your blood or transmitting messages to and from your brain. These specialists are known as differentiated cells.

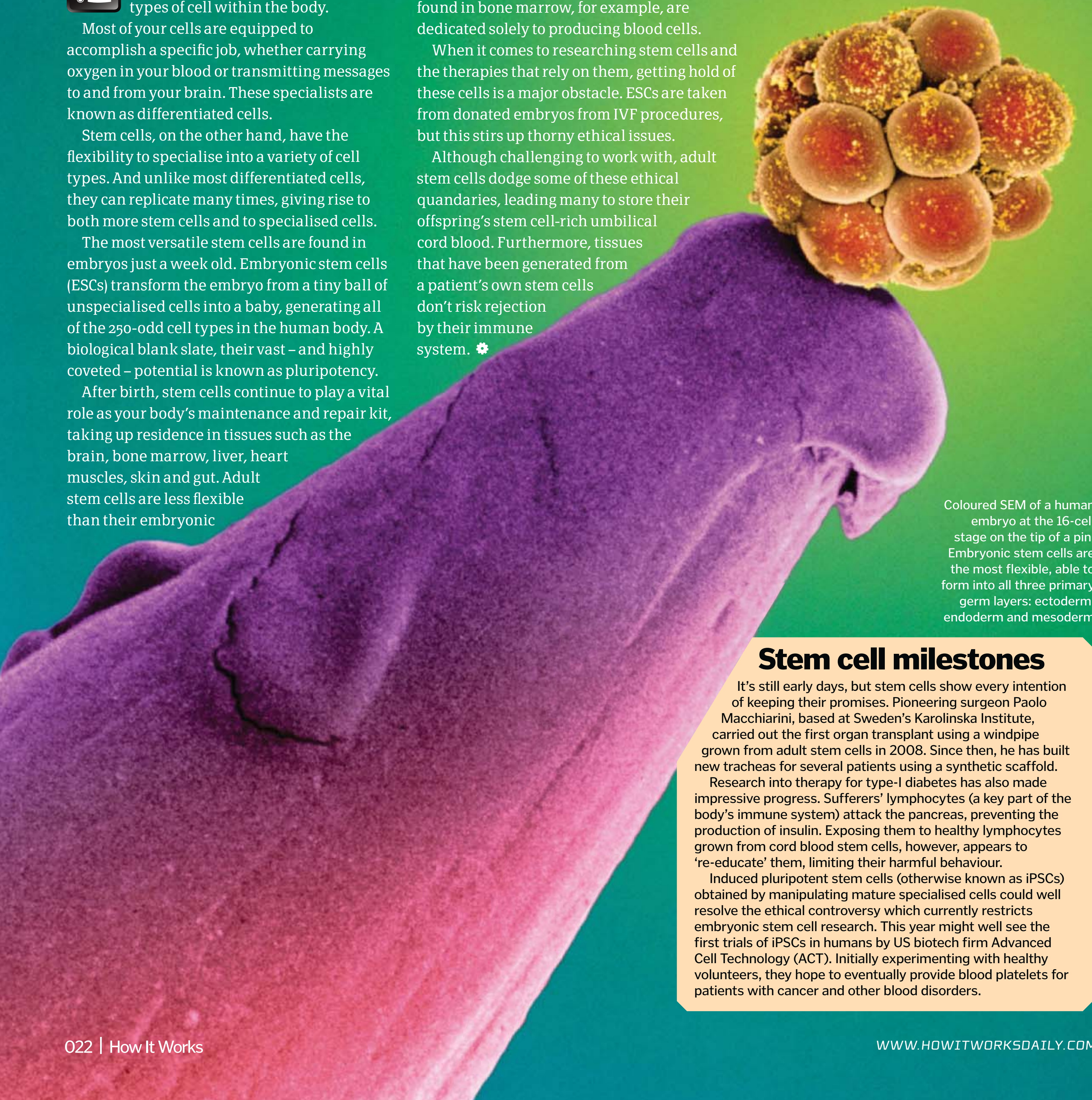
Stem cells, on the other hand, have the flexibility to specialise into a variety of cell types. And unlike most differentiated cells, they can replicate many times, giving rise to both more stem cells and to specialised cells.

The most versatile stem cells are found in embryos just a week old. Embryonic stem cells (ESCs) transform the embryo from a tiny ball of unspecialised cells into a baby, generating all of the 250-odd cell types in the human body. A biological blank slate, their vast – and highly coveted – potential is known as pluripotency.

After birth, stem cells continue to play a vital role as your body's maintenance and repair kit, taking up residence in tissues such as the brain, bone marrow, liver, heart muscles, skin and gut. Adult stem cells are less flexible than their embryonic counterparts, generating a more limited range of cell types. The haematopoietic stem cells found in bone marrow, for example, are dedicated solely to producing blood cells.

When it comes to researching stem cells and the therapies that rely on them, getting hold of these cells is a major obstacle. ESCs are taken from donated embryos from IVF procedures, but this stirs up thorny ethical issues.

Although challenging to work with, adult stem cells dodge some of these ethical quandaries, leading many to store their offspring's stem cell-rich umbilical cord blood. Furthermore, tissues that have been generated from a patient's own stem cells don't risk rejection by their immune system.



Coloured SEM of a human embryo at the 16-cell stage on the tip of a pin. Embryonic stem cells are the most flexible, able to form into all three primary germ layers: ectoderm, endoderm and mesoderm

Stem cell milestones

It's still early days, but stem cells show every intention of keeping their promises. Pioneering surgeon Paolo Macchiarini, based at Sweden's Karolinska Institute, carried out the first organ transplant using a windpipe grown from adult stem cells in 2008. Since then, he has built new tracheas for several patients using a synthetic scaffold.

Research into therapy for type-I diabetes has also made impressive progress. Sufferers' lymphocytes (a key part of the body's immune system) attack the pancreas, preventing the production of insulin. Exposing them to healthy lymphocytes grown from cord blood stem cells, however, appears to 're-educate' them, limiting their harmful behaviour.

Induced pluripotent stem cells (otherwise known as iPSCs) obtained by manipulating mature specialised cells could well resolve the ethical controversy which currently restricts embryonic stem cell research. This year might well see the first trials of iPSCs in humans by US biotech firm Advanced Cell Technology (ACT). Initially experimenting with healthy volunteers, they hope to eventually provide blood platelets for patients with cancer and other blood disorders.

5 TOP FACTS STEM CELLS

All new
1 Thanks to stem cells, you get a whole new skin approximately every four weeks, a new gut lining every few days and a staggering 2 million new red blood cells every second.

Pearly whites
2 Researchers discovered stem cells in the dental pulp of human teeth (DPSCs) in 2000. As time goes on, we continue to find them lurking in new parts of the body.

Skin on demand
3 Doctors have used skin stem cells to grow entire sheets of epidermis in the lab, only with no hairs or sweat glands. This skin can be used as grafts for patients with severe burns.

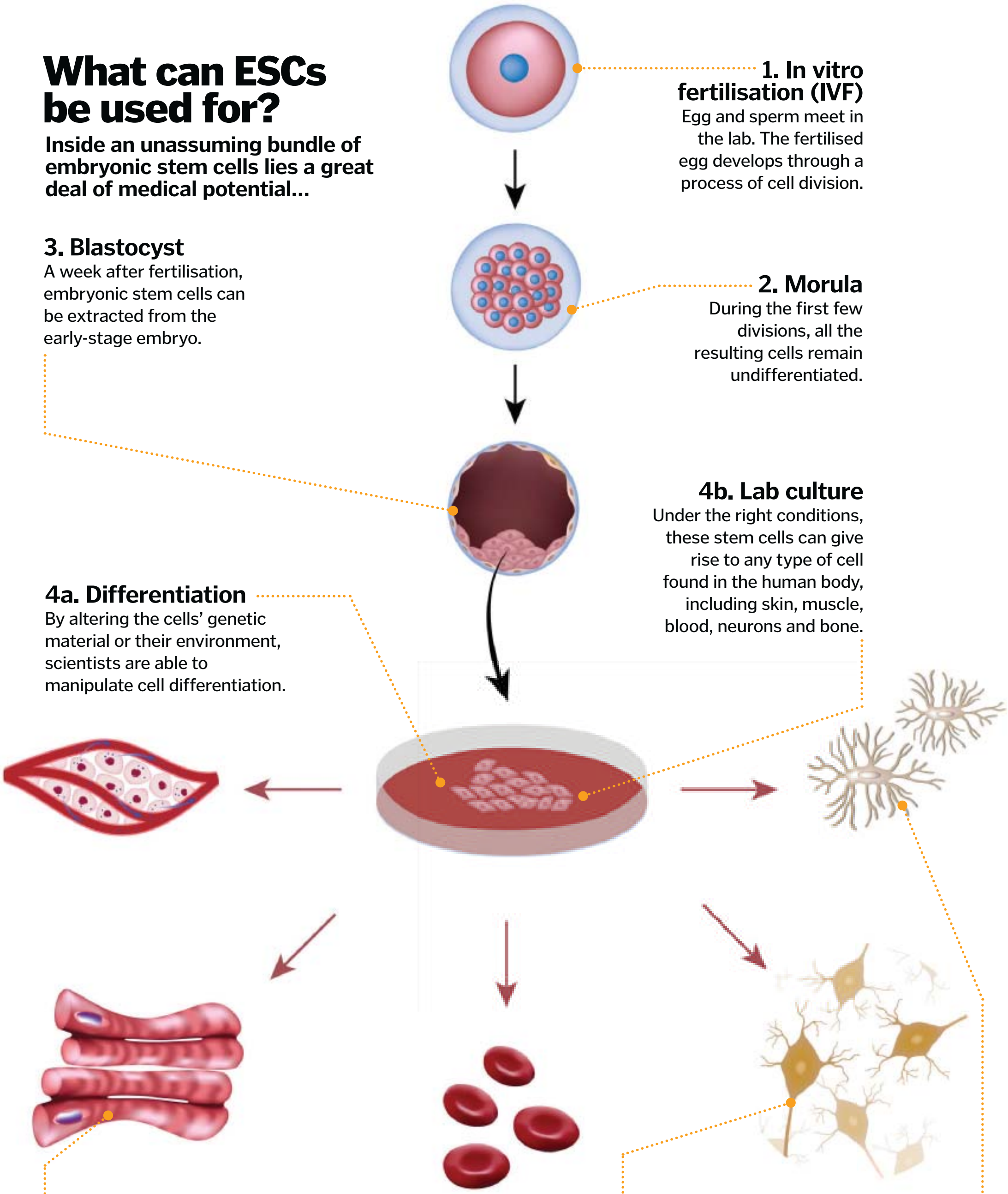
Stem cell bombshell
4 Carbon-14 produced by Cold War nuclear bomb testing has enabled researchers to determine that the heart can regenerate itself (very slowly) thanks to stem cells.

Lifesavers
5 In the last 20 years, more than 20,000 patients have received umbilical cord blood transplants – for the most part treating leukaemia and blood disorders in children.

DID YOU KNOW? *Salamanders' impressive stem cells mean they can regenerate their legs, heart, brain, spine and more*

What can ESCs be used for?

Inside an unassuming bundle of embryonic stem cells lies a great deal of medical potential...



1. In vitro fertilisation (IVF)
Egg and sperm meet in the lab. The fertilised egg develops through a process of cell division.

2. Morula
During the first few divisions, all the resulting cells remain undifferentiated.

3. Blastocyst
A week after fertilisation, embryonic stem cells can be extracted from the early-stage embryo.

4a. Differentiation
By altering the cells' genetic material or their environment, scientists are able to manipulate cell differentiation.

4b. Lab culture
Under the right conditions, these stem cells can give rise to any type of cell found in the human body, including skin, muscle, blood, neurons and bone.

5a. Muscle cells
Scientists believe muscle cells grown from stem cells could slow the progress of muscular dystrophy and even repair damaged hearts.

5b. Neurons
Healthy brain cells grown in the lab could treat Parkinson's, multiple sclerosis and spinal injuries.

5c. Bone grafts
Embryonic stem cells could be used to grow bone grafts which may eventually help patients with breaks, fractures or birth defects.

Stem cells to the rescue

Allowing researchers to watch cell specialisation unfold before their eyes, stem cells deliver unprecedented insight into many diseases and birth defects. Stem cells share many traits with cancer cells and could therefore reveal some of their secrets; some speculate that cancer may even be driven by out-of-control stem cells.

Many future treatments aim to harness stem cells' regenerative properties. Healthy cell and tissue transplants could patch up patients with a variety of different complaints, from diabetes to Parkinson's. Recent trials suggest, for instance, that injecting failing hearts with stem cells could grant them a new lease of life.

Tissues made from stem cells may also enable new medications to be tested on human cells in the early stages of drug development. One day, entire organs might be grown in the lab from patients' own stem cells, dramatically cutting waiting lists for organ donors. In the meantime, scientists need plenty more time to research the finer details of controlling cell differentiation.

Professor of Stem Cell Science

Newcastle Uni's Majlinda Lako discusses super cells

What's left to learn about stem cells?
We know that stem cells are present at all stages of our life. Stem cells found in early embryos have the potential to become different types of cell, while adult stem cells are more specific. The questions we are trying to answer are: can we identify all stem cells? Can we grow them in large numbers in the lab? Can we make them give rise to any cells we wish? Can we use stem cells to treat cancer, ageing and degenerative diseases?

Does every multicellular organism have stem cells?
Yes. In mammals, there are two main types of stem cells: embryonic, which are generated from early embryos, and adult, which are found in various tissues and contribute to the repair and replenishment of our tissues. For a long time it was thought that once the stem cells changed to form the various cells that make up our organs, it was impossible to make them revert back to the initial stem cell state. However, the Nobel prize winner Shinya Yamanaka reported in 2006 that adult cells can be turned back to the embryonic stage by simple genetic manipulation.

Who first discovered stem cells?
The concept of stem cells was first mentioned by Valentin Haecker and Theodor Boveri in the 19th century. In parallel, Artur Pappenheim, Alexander Maksimov, Ernst Neumann and others used it to describe a proposed origin of the blood system. As the field progressed, the term 'stem cell' has been used to describe the capacity of stem cells for self-renewal as well as the ability to give rise to all cell types that make up our bodies.

Do stem cells have to be prompted in some way to repair the body?
Adult stem cells need prompting if a quick repair is needed, and we can achieve this in the lab. Stem cell prompting in the body is a bit more tricky, but can occur in response to specific stress or injuries.

"A coma occurs when the reticular activating system is disrupted by brain injury or illness"

The biology of comas

It means 'deep sleep' in Greek, but a coma is no such thing…

A coma is a state of unconsciousness in which the brain is alive but functioning at its lowest level of alertness. Normally the brain transmits continuous chemical signals from the cerebral cortex (the outer layer) to the brainstem (which is attached to the spinal cord). The cerebral cortex is responsible for high-level thoughts such as feelings, while the brainstem regulates automatic functions like the heart pumping.

In order to 'talk' to each other signals are channelled between the brainstem and the cerebral cortex via a neural pathway called the reticular activating system (RAS). The RAS is like the brain's light-switch – turn it off and you switch off consciousness. When functioning normally the RAS sends messages from an area called the reticular formation, through the thalamus (a mass of neurons at the top of the brainstem) to the cerebral cortex.

During sleep the neurons in the RAS fire at a lower rate but are still active. But in a coma the activity is too minimal for the cortex to process information, leaving the person without awareness.

A coma occurs when the RAS is disrupted by brain injury or illness. Meningitis, for example, can cause swelling in the brain which presses on blood vessels and blocks oxygen to vital areas.

Doctors grade a patient's degree of consciousness with the Glasgow Coma Scale (GCS), measuring eye opening, as well as verbal and motor responses. The lower the score, the deeper the coma.

A person in a coma may die, recover or transition into a vegetative state. A person in a vegetative state has more lower-brain function (actions like breathing) and slightly more upper brainstem functions such as being able to open their eyes. A coma is not the same as 'locked-in syndrome' where the person is fully conscious but paralysed.

Coming out of a coma

Recovery depends on the cause of the coma. Infection-induced comas may reverse with antibiotics, while excess pressure may resolve by draining fluid. Comas rarely last more than two to four weeks, but recovery is gradual. Patients may be alert for only a few minutes, progressing to longer periods. Their outcome relates to their Glasgow Coma Scale result – those who scored lowest in the first 24 hours will likely die or remain in a vegetative state, while those who score at the higher end may make a full recovery. Coma survival rates are around 50 per cent. After a coma the patient may only recall memories after coming to and will usually wake in a profound state of confusion, not knowing how they got there. However, they tend to regain brain function gradually, often with the help of physiotherapy and occupational therapy to relearn basic skills like walking, talking and eating.

Brain activity comparison

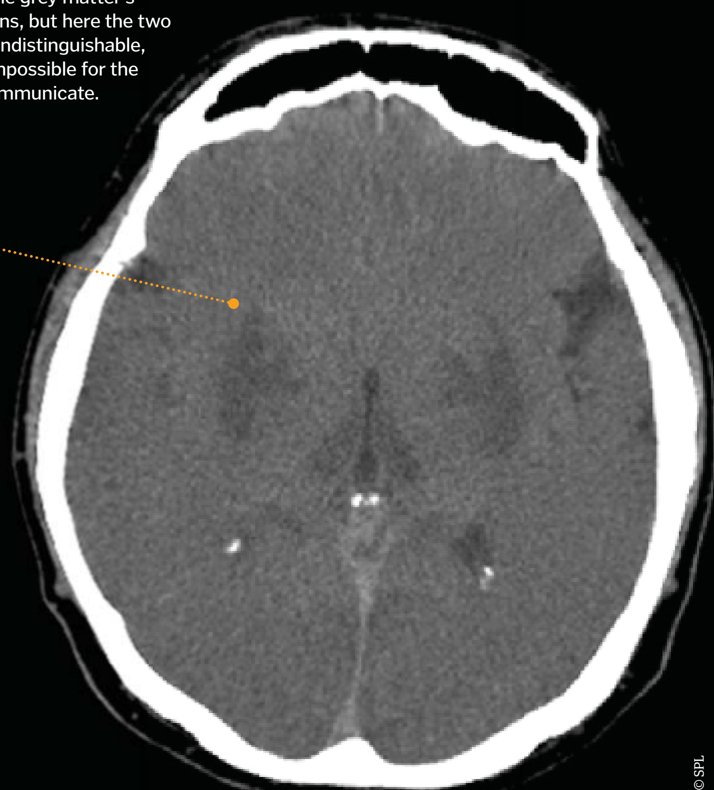
See a healthy brain and a comatose brain side by side

Healthy brain

This MRI scan shows the normal anatomy of the cerebral hemispheres. Two types of brain tissue are visible: grey matter which performs computations (the darker tissue) and white matter (lighter fibres), which transmits signals between the various regions of this complex organ.

Brain in a coma

This scan shows irreversible destruction of the white and grey matter of the brain's frontal and cerebral regions (upper centre). Normally the white matter transmits the grey matter's computations, but here the two are almost indistinguishable, making it impossible for the organ to communicate.



RECORD BREAKERS
FASTEST DROPOUT

1,357.6km/h

TOP TERMINAL VELOCITY
This is the current world record during a human skydive, achieved by Felix Baumgartner on his epic 39-kilometre (24-mile)-high jump in 2012.

DID YOU KNOW? *The average terminal velocity that a skydiver will obtain is around 55.5 metres per second*

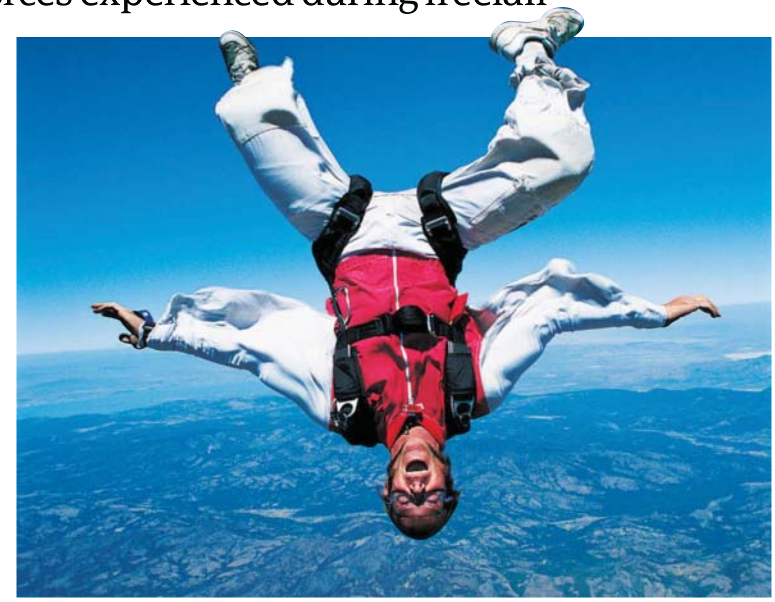
What is terminal velocity?

Get up to speed with this critical balance of forces experienced during freefall

Terminal velocity is the constant speed achieved by an object freefalling through a gas (eg air) or liquid. Terminal velocity is therefore reached when its speed is no longer increasing or decreasing – ie the drag force and buoyancy are equal to the downward force of gravity – with the net force acting on it balancing out at zero.

The two main factors that dictate an object's terminal velocity on Earth are its weight and surface area, with heavier, small surface area objects having a greater velocity. For example, a lead ball will have a much higher terminal velocity than a sheet of paper as the former both weighs more and occupies less space.

The importance of surface area is due to the gas or liquid medium's drag effect. For example, the air in Earth's atmosphere generates resistance due to its molecules colliding into any falling body and creating an upward force in opposition to gravity. This is why if two differently weighted objects are dropped into a vacuum at the same speed, they will experience the same acceleration (as shown in the famous feather/hammer drop test conducted on the Moon during the Apollo 15 mission.



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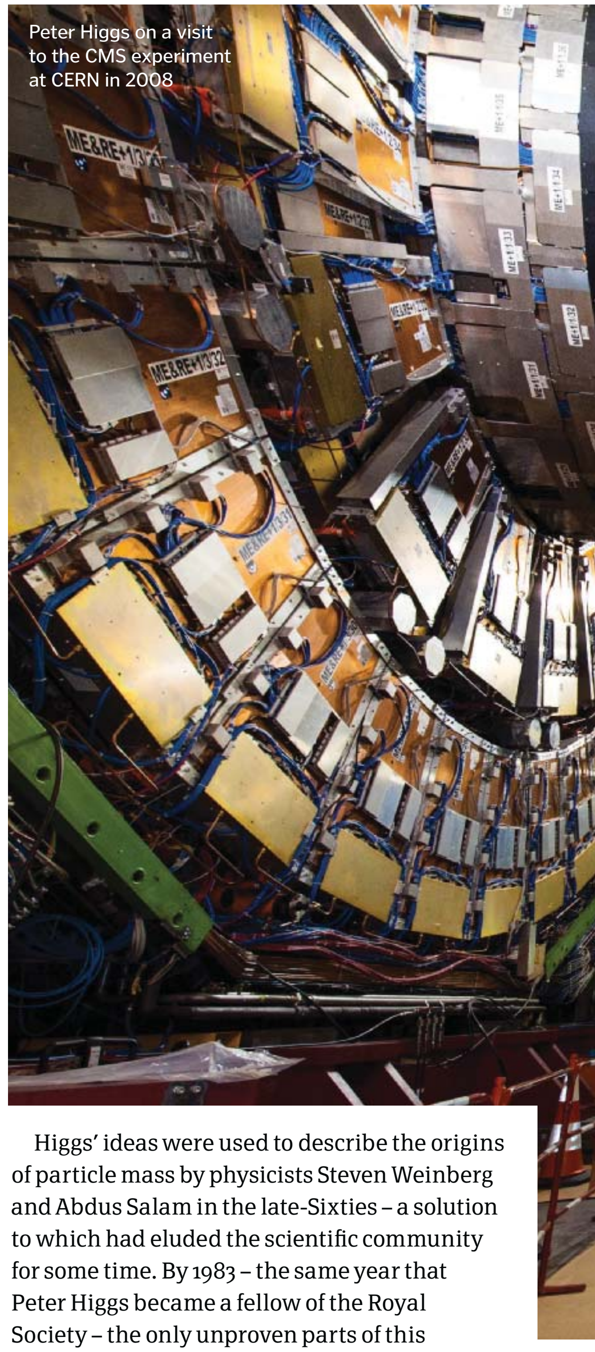
HEROES OF... SCIENCE
HISTORY'S MOST INFLUENTIAL SCIENTISTS



Peter Higgs on a visit to the CMS experiment at CERN in 2008

Peter Higgs

Well known in the scientific community for decades, it's only with the suspected discovery of the Higgs boson in 2012 that this physicist shot into the limelight

We can safely say that the 4 July 2012 discovery of a new particle, likely to be the elusive Higgs boson, had to be the biggest scientific announcement of the year. For most, it was enough to know that the Large Hadron Collider (LHC) – that huge, super-expensive particle accelerator in Switzerland – had given real weight to some decades-old but cohesive physical theory. Some impressive figures were released, then impossible speeds and inconceivably small theoretical particles existing for infinitely short expanses of time were mentioned, and our collective imaginations were captured. For its namesake Peter Higgs though, it must have felt like the ultimate validation of his entire career.

Higgs was born in Newcastle-upon-Tyne, UK, in 1929. He graduated from King's College in the University of London with a first-class degree in Physics then went on to secure a Master's and finally a doctorate in 1954. It was during his work as a research fellow and a lecturer that Higgs began the basis of a paper that would help describe the very nature of mass, even if it was completely disregarded at first. Higgs' work began in quantum field theory – the surreal world of the forces that bind subatomic particles and an exciting new area at the time.

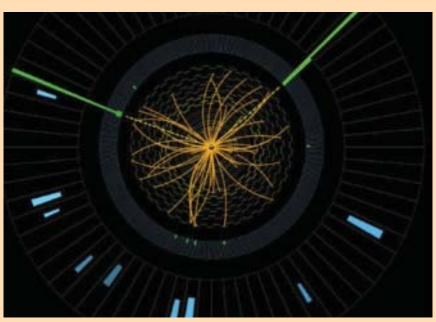
His first paper on the Goldstone boson was picked up and published by a physics journal edited at the only recently founded CERN in Switzerland that same year. To his dismay though, his next paper – finished in 1964 – was rejected on the basis that it bore no relevance to physics. This paper described the radical concept of what became known as the Higgs mechanism, a scalar field present in all points of space, which gives particles mass. The Higgs mechanism was independently discovered by several other leading physicists in the same year, however none of them made any mention of a massive boson, which Higgs had gone on to include in a revision of the same paper.

Higgs' ideas were used to describe the origins of particle mass by physicists Steven Weinberg and Abdus Salam in the late-Sixties – a solution to which had eluded the scientific community for some time. By 1983 – the same year that Peter Higgs became a fellow of the Royal Society – the only unproven parts of this electroweak theory were the Higgs field and the Higgs boson, but it took nearly 20 years and physical experiments of an unprecedented scale in the LHC and beyond, to finally draw a line under the Higgs boson.

Peter Higgs retired in 1996 from a career that also saw him win the Rutherford Medal and the Dirac Medal. In the wake of 2012's CERN announcement, he has received praise from many notable peers – including Stephen Hawking, who has publicly recommended him for the Nobel Prize in Physics.

The big idea

The existence of the Higgs boson hasn't been proven absolutely, but CERN's experiments did confirm the existence of a new particle that is consistent with Higgs' theory. For most physicists, there's no doubt it's the Higgs boson. What this particle proves is the existence of the Higgs field, which allows the building blocks of our universe to gain mass and form stars, planets, galaxies and everything around us. Currently, it provides the answers to the last few burning questions in the Standard Model of Physics, and in the future it could prove integral to science.



A life's work

The big events that led to the discovery of this tiny particle

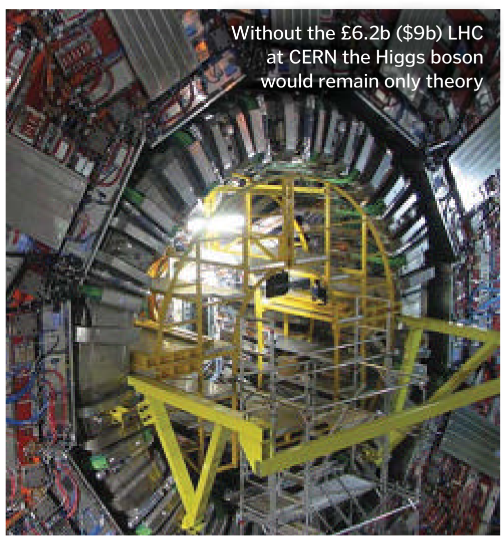
1929
Born on 29 May, the family moves around a lot as Higgs' father is a sound engineer for the BBC.

1954
Finishes his PhD at King's College London (right) and goes on to lecture at the University of Edinburgh.

1964
He describes the Higgs mechanism in a paper, which is rejected. He later revises it to include the Higgs boson.

1983
W and Z bosons are discovered, leaving only the Higgs particle to confirm the electroweak theory. Higgs also enters the Royal Society.

1991
Higgs becomes a fellow at the prestigious Institute of Physics, London.



Without the £6.2b ($9b) LHC at CERN the Higgs boson would remain only theory

Top 5 facts: Peter Higgs

1 High five
Physicists use standard deviation to determine an official discovery or not. At 5 sigma, the level reached when scientists pored over the Higgs boson experiments, there's a one in 3.5 million chance the data is a fluke.

2 The 'God particle'
The Higgs boson has been nicknamed the 'God particle', attributed to the Nobel prize-winning physicist Leon Lederman, whose book originally referred to it as the 'goddamn particle', but this was later amended.

3 Need for speed
Two of the highest-energy particle accelerators in the world were employed to search for the Higgs boson. In addition to the LHC, the Fermilab's Tevatron, near Chicago, IL, was used.

4 Big Bang
Conditions conducive to the creation of the Higgs boson – similar to those at the time of the Big Bang – were created by smashing elementary particles together at nearly the speed of light.

5 Humble Hawking
There were many who doubted the existence of the Higgs boson, including Professor Stephen Hawking, who bet Gordon Kane of Michigan University $100 that CERN would find nothing.

In their footsteps…

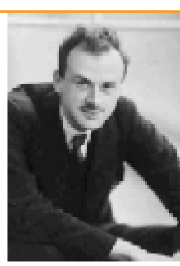
Ken Currie
The celebrated Scottish artist Ken Currie was commissioned by the University of Edinburgh to paint a portrait of Peter Higgs in 2008. He admitted to being inspired by Higgs' work – not claiming to understand his theory, per se, but grasping the sublime and 'beautiful' nature of his solution.

Sir David Wallace
Higgs was Wallace's advisor while he was studying a PhD in elementary particle theory. Formerly a researcher at Princeton University and a lecturer at Southampton University, it's for his work as director of the Edinburgh Parallel Computing Centre that he was awarded a CBE.

"During his work as a lecturer Higgs began the basis of a paper that would help describe the very nature of mass"

1996
Higgs retires and becomes emeritus professor at the University of Edinburgh.

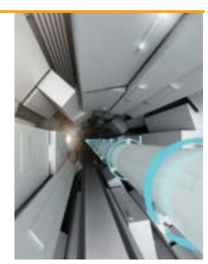
1997
He receives an award for his work in theoretical physics, named after a hero of his: theoretical physicist Paul Dirac (right).



2004
Another award – this time the Israeli Wolf Prize in Physics, though Higgs refuses to fly to Jerusalem to receive it on moral grounds.

2011
The results of CERN's initial experiments with the LHC in December are extremely positive, but more tests are needed to be certain.

2012
The strongest indication of a new particle with significant mass is announced by CERN in July. For his work, Higgs is made a Companion of Honour at the start of 2013.



25 TECH MYTHS EXPLAINED

Separating fact from fiction can be very hard – unless you've read our handy guide…

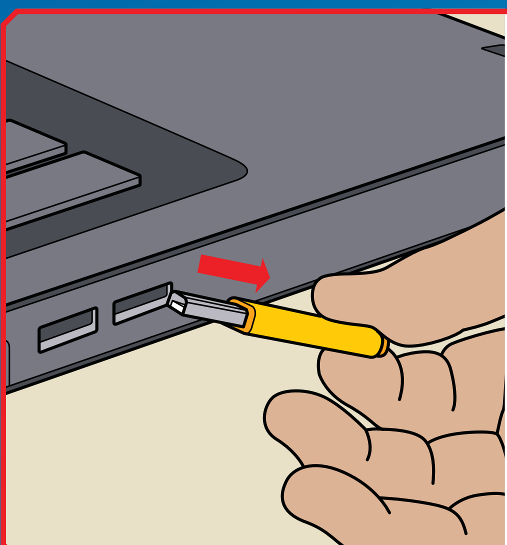
Humans are gullible animals. The essence of scientific progress is that we constantly seek explanations for the things we see around us. But this is also the foundation of superstition because when no satisfying pattern of cause and effect exists, we are likely to invent one. If you have ever imagined you can make the clouds disappear by staring hard at them, or believed some far-fetched medical claims, you have fallen victim to the power of wishful thinking. But don't worry, you're quite normal. Although magic and fairytales have long been replaced by technology, the human ability to invent myths continues unchecked. And what makes it even harder is that things that seem plausible are fantasy, whereas others that appear incredible are actually true. In this feature we sort the lore from the law to reveal the truth behind some of today's biggest technological myths.

1 Leaving home appliances on is a fire hazard

Electrical fires are usually caused by overloaded sockets, moisture reaching the electrics, blocked vents or combustible substances reaching hot components. Tumble-dryers and heaters are the most dangerous, but there are rare cases of even TVs starting fires due to faults that led them to overheat.
TRUSTED

2 Marching soldiers can topple a bridge

This happened once in 1831, when the Broughton Suspension Bridge, near Manchester, collapsed after 74 soldiers marched at precisely the resonant frequency of the bridge. But later examination showed that a bolt had been badly forged. All modern bridges have much higher safety margins.
BUSTED



3 Switching off a PC or removing a USB stick incorrectly can damage the device

It won't physically damage the hardware, however there's a small risk of damage to your data. Most obviously, any unsaved work in open applications will be lost. But it's also possible to corrupt the filing system on the hard disk, which keeps track of where all the files are. This can usually be repaired automatically by the system, but it can be quite a long process so it just makes your PC or console much slower to start next time. For USB disks and memory sticks the same thing applies. If you don't eject the device before you physically unplug it, you are running a small but real risk of data corruption, so the moral of the story is: be patient with your computing devices on shut down.
TRUSTED

4 Spy satellites are watching us from space

While the exact details of spy satellite capabilities are classified, the best estimates from civilian surveillance experts are that the modern ones can make out objects as small as four to ten centimetres (1.6-3.9 inches) across. Not quite good enough to read a number plate or identify a face. Spy satellites also use low orbits, which means that they aren't overhead for more than about 20 minutes at a time. For this reason drone aircraft are far better for spying on individuals.
BUSTED

Laptops cause infertility
1 This idea stems from a 2011 study that found Wi-Fi signals from laptops could kill sperm. However the study has since been criticised as it used unrealistic test conditions.

Jailbreaking is illegal
2 It will void your warranty, but there is absolutely nothing illegal about jailbreaking your own iPhone to use a different SIM card or install apps that aren't approved by Apple.

MP3 is substandard
3 If you think you can tell MP3 from lossless music files, then you are fooling yourself. Research has shown they are indistinguishable in real-world situations on many occasions.

Pricey cables are better
4 'Deluxe' HDMI cables that cost £30, £50 or even £100 more are simply scams that offer no benefit to the quality of the picture or sound you get on your screen.

QWERTY is slower
5 The QWERTY keyboard layout was designed to reduce jams in mechanical typewriters, but by separating frequently used keys, not by actually slowing down typing speeds.

DID YOU KNOW? *The magnetic fields from solar flares can play havoc with conductors like wires and pipelines on Earth*

5 You should never use your mobile at a petrol station

The fear is that the electromagnetic (EM) radiation from a mobile phone could impart enough energy to ignite petrol vapour directly or that it could induce currents in nearby metal objects and trigger a spark with the same effect. But a study found that in 243 petrol station fires around the world between 1994 and 2005, none were caused by mobile phones. In fact, there isn't a single confirmed case of this ever happening. Even a lit cigarette isn't hot enough to ignite petrol vapour. You need a naked flame or a spark, and mobile phones have low-voltage batteries that aren't capable of producing either.

Petrol station fires are very rare and nearly all are caused by sparks from static electricity igniting petrol vapour. This requires just the right mix of air and vapour, which is much less likely to occur now that pumps have vapour-recovery systems installed.

BUSTED

6 Fibre-optic broadband works faster

The tech certainly allows for much faster data rates, but how much of that you actually see depends on your ISP. A study by Ofcom in 2010 found average broadband speeds in the UK were around 6.2Mbps, compared with the average advertised theoretical speed of 13.8Mbps. However, fibre-optic broadband does seem to come closer to its advertised speed than ordinary ADSL broadband – eg Virgin Media customers on 'up to 50Mbps' packages managed an average of 43.9-47.2Mbps.

TRUSTED

7 Gun silencers totally muffle a fired shot

More technically known as suppressors, they do make the gun quieter – but not by much. Indeed, for the person firing the gun, the shot is still as loud as a pneumatic drill! Suppressors make gunshots harder to locate and, at ranges longer than 300 metres (980 feet), can make the shot silent *for the target*.

BUSTED

8 Airport security machines destroy electronic devices

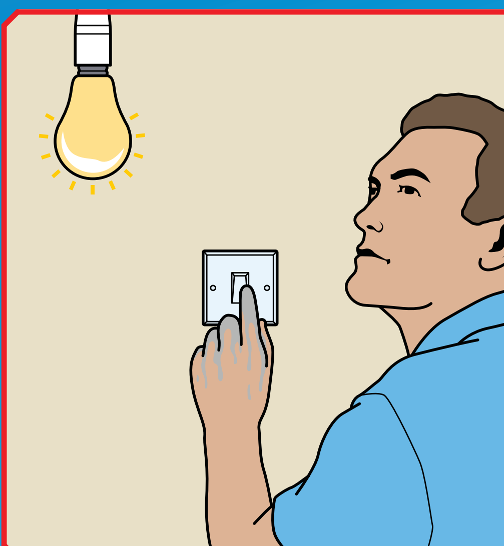
Conveyor belt luggage scanners use X-rays, millimetre waves or submillimetre 'T-waves'. These are all forms of electromagnetic radiation but they are low intensity and the radiation frequency is non-ionising, so it won't affect electronics/memory cards. According to the US Transportation Security Administration, the X-ray dose from a scanner is much less than you would normally receive due to the slightly higher background radiation while flying. The metal detectors you walk through use powerful magnets though and could pose a risk to the hard disks in laptops and some video cameras. But these items have to be scanned on the conveyor belt anyway.

BUSTED

9 The most economical speed at which to drive your car is 55mph

Car engines are actually most efficient at a particular number of revs, rather than road speed. For most cars this is around 2,000 rpm. As you accelerate, the revs rise above this and you change up a gear to maintain efficiency. As soon as you reach fifth gear, with the revs around 2,000, you are at the most efficient speed. That's just 56-74 kilometres (35-45 miles) per hour for the majority of cars. 89 kilometres (55 miles) per hour is often quoted as a more economical compromise to encourage drivers to slow down from 113 kilometres (70 miles) per hour. It doesn't mean that 55 is the optimum speed.

BUSTED

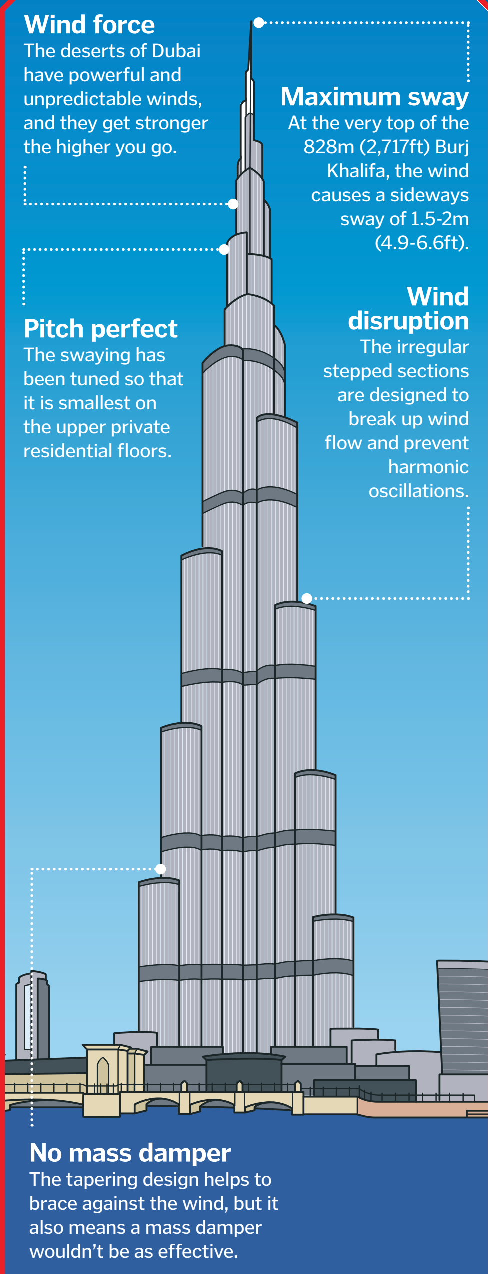


10 If you touch a light switch with wet hands you will be electrocuted

This one's a bit of a grey area because while it might be theoretically possible this could happen, it's very unlikely. Your hands would have to be wet enough for water to drip past the rocker to the live wires behind it and complete a circuit with your finger in the time it takes for you to flick the switch. This would give you an electric shock but probably only at your fingertips. To electrocute you, on the other hand, the current would have to flow through your body and stop your heart. That's much more likely if your whole body is wet, which is why bathroom light switches tend to use pull cords to keep your wet hands away from the wiring, just to be on the safe side.

TRUSTED

"The semiconductor industry has been able to maintain this trend only by spending more on R&D"



11 Skyscrapers sway when it gets windy

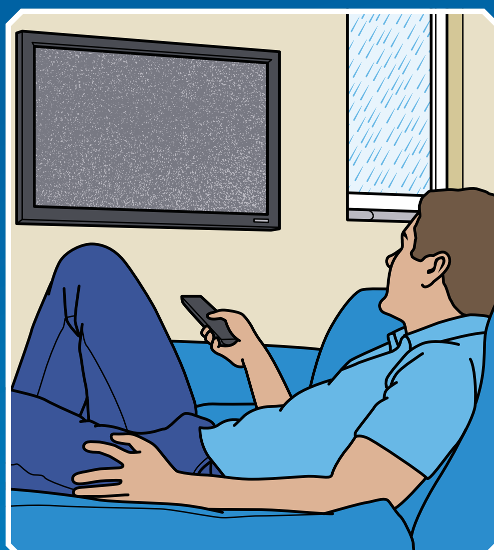
There's no such thing as a perfectly rigid substance; even concrete will flex very slightly. Most of the time you won't feel it, but in high winds skyscrapers can sway from side to side by up to a metre on the top floors. To combat this, tall skyscrapers now have tuned mass dampers in the upper floors. These are several-hundred-ton blocks of concrete, with a computer-controlled hydraulic ram that moves the block sideways to offset the sway. This can also reduce more violent swaying from earthquakes.
TRUSTED

12 More megapixels make for better photos

When digital cameras first appeared, the resolution of the sensor was low enough that you could easily make out the individual pixels when they were printed out. But camera resolutions very quickly improved to the point where individual pixels were imperceptible. For instance, for 6x4 prints you only need a two-megapixel camera to be able to print at the same quality as the photos in this magazine. And the most you will *ever* need is seven megapixels. This is enough to print an A3 page at magazine resolution and, if you print out any larger than that, you would need to stand farther back to look at it, so the effective resolution remains the same. Once you hit this megapixel threshold, there are three main factors that affect the quality of your snaps: the skill of the photographer, the quality of the camera lens and the size of the CCD sensor in the camera. The physical size of the CCD sensor matters because it increases the amount of light gathered, which reduces image noise and increases depth of field.
BUSTED

13 Living near pylons can cause cancer

Radon is a naturally occurring radioactive gas that's part of the background radiation dose we all receive. A 1999 study at Bristol University found the electromagnetic field near pylons/power cables attracts the radioactive decay products of radon. In theory this could mean that people living near to power lines might be exposed to a higher dose. However at least 20,000 UK families live near power lines and a huge study published in *The Lancet* found no link to cancer whatsoever – at least in children.
BUSTED



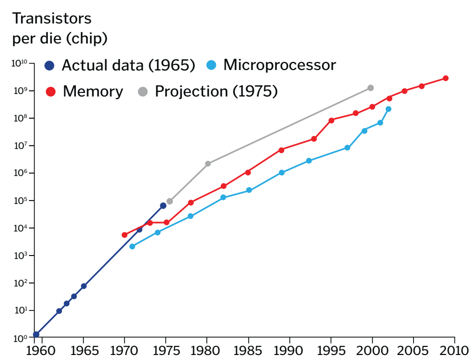
14 Rain disrupts satellite TV

Satellite TV uses EM frequencies in the microwave range which is strongly absorbed by water. Rain reduces the strength of the signal, but the broadcaster minimises uplink interference by increasing the power and using multiple uplink stations at different locations, so you'll normally only notice it during very heavy rain that affects downlink reception.
TRUSTED

15 PC power is still doubling every two years

Gordon Moore, who co-founded technology giant Intel, predicted back in 1975 that the number of transistors on a computer chip would double every two years. This is referred to as Moore's Law, but there's nothing inevitable about it. The semiconductor industry has been able to maintain this trend only by spending more and more on research and development. In ten years or so, miniaturisation will bottom out at atomic scale, but bigger chips and new tech could still allow the power of each chip to increase. For now at least, Moore's Law still holds.
TRUSTED

When Moore first put forward his theory in 1965, he suggested transistors would double annually, but revised this to biannually ten years later



16 You should warm your engine before driving in winter

Look in the manual for your car. Manufacturers will tell you that the best way to warm up your car is to drive it. This gets all the components to their ideal operating temperature as quickly as possible. Idling the engine first just wastes fuel and increases emissions.
BUSTED

STRANGE BUT TRUE
ALIEN CONSPIRACY

What was buried in the New Mexico desert in 1983?

A Alien photos **B** A crashed UFO **C** E.T.

Answer:
After the Eighties videogame console market crash, Atari was stuck with 5 million unsold cartridges for its game based on Spielberg's 1982 hit film *E.T.* As a result, 14 truckloads of cartridges were crushed and buried in Alamogordo, New Mexico.

DID YOU KNOW? *Using high-speed flash cards does not allow photographs to be taken faster, merely stored faster*

17 Using a phone during a flight can affect the navigation equipment on a plane

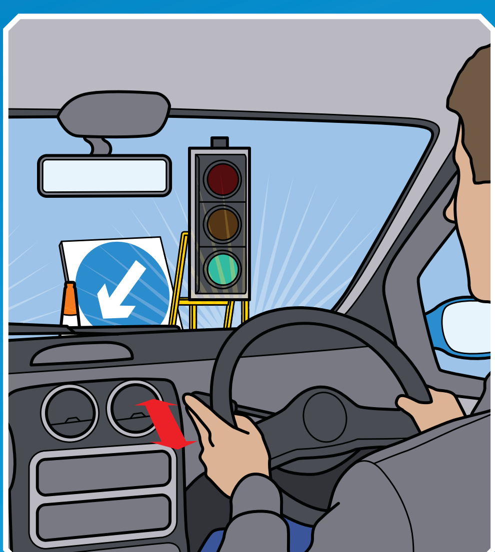
There are anecdotal reports of interference from various electronic devices (including DVD players, which are currently allowed) and some simulation studies suggest that interference is theoretically possible. Airlines continue to enforce a no-phones policy using the same precautionary principle adopted by petrol stations (see myth 5 on page 29 for more information). However, a 2011 poll found that three per cent of British holidaymakers had forgotten to turn off their mobile phone when they flew. That would mean almost 6.5 million switched-on phones flew that year, suggesting the risk is – at worst – very small.
BUSTED

18 Passwords must be super-complicated

A password so complicated you forget it is less secure as you'll probably write it down close to your computer. You are also more likely to reuse it across lots of websites. Just use three unrelated words, such as 'penguintoastwonderful'.
BUSTED

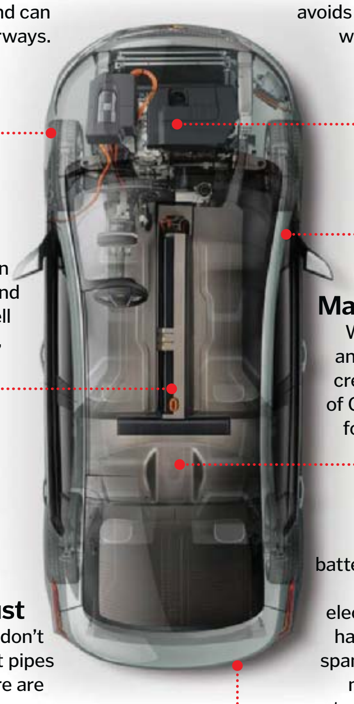
19 Signals turn green if you flash your lights

Some traffic lights use microwave sensors to detect cars. If the other direction is clear they will often turn green just as you approach. Flashing your lights makes no difference.
BUSTED



20 Electric cars are 100% green

Fully electric cars use batteries to power electric motors. There's no internal combustion engine, so they don't emit greenhouse gases or other forms of air pollution. But the batteries still have to be charged by plugging them into the electricity grid and the power that this uses has to be generated somewhere. Electric cars also create more pollution during manufacture than petrol cars, particularly the batteries.
BUSTED



Battery myths

21 Fully draining a rechargeable battery makes it last longer next time

Lithium batteries actually degrade slightly when they are left fully discharged. 'Charge memory' only ever applied to the old NiMH and NiCd batteries. Lithium cells last longest when kept at 40-70 per cent charge. **Busted**

22 Rubbing a battery helps to revive it

Batteries work via a chemical reaction, not static electricity. And rubbing it will only make it warmer, which reduces performance. Unplugging a dead battery can cause a very short-term recovery. **Busted**

23 Batteries last longer when cold

Ordinary alkaline batteries only discharge at two per cent per year at room temperature, but NiMH and NiCd batteries discharge much quicker – two per cent per day. Storing these batteries in the freezer will let them keep 90 per cent of their charge for a month. **Trusted**

24 You should charge new devices to 100 per cent capacity

It doesn't extend the physical life of the battery, but it may help calibrate the software that measures the remaining charge life. **Trusted**

25 Closing apps on your phone helps the battery last longer

Leaving Angry Birds running on the screen will drain your battery, but if you switch to another app, you needn't close the game – the OS suspends it automatically. **Busted**

"The central computer can instantly calculate the probability of the Phalanx taking a target out"

The missile killer

The Phalanx CIWS is one of the most advanced and brutal gun turrets on the planet – find out why now

The Phalanx is a close-in weapon system (CIWS) – a largely defensive piece of kit designed to shoot down incoming anti-ship missiles. The Phalanx is arguably the most cutting-edge CIWS currently around, sporting a powerful 20-millimetre (0.8-inch) M61 Vulcan autocannon, advanced dual-antenna Ku-band radar array and huge 1,550-round munitions drum.

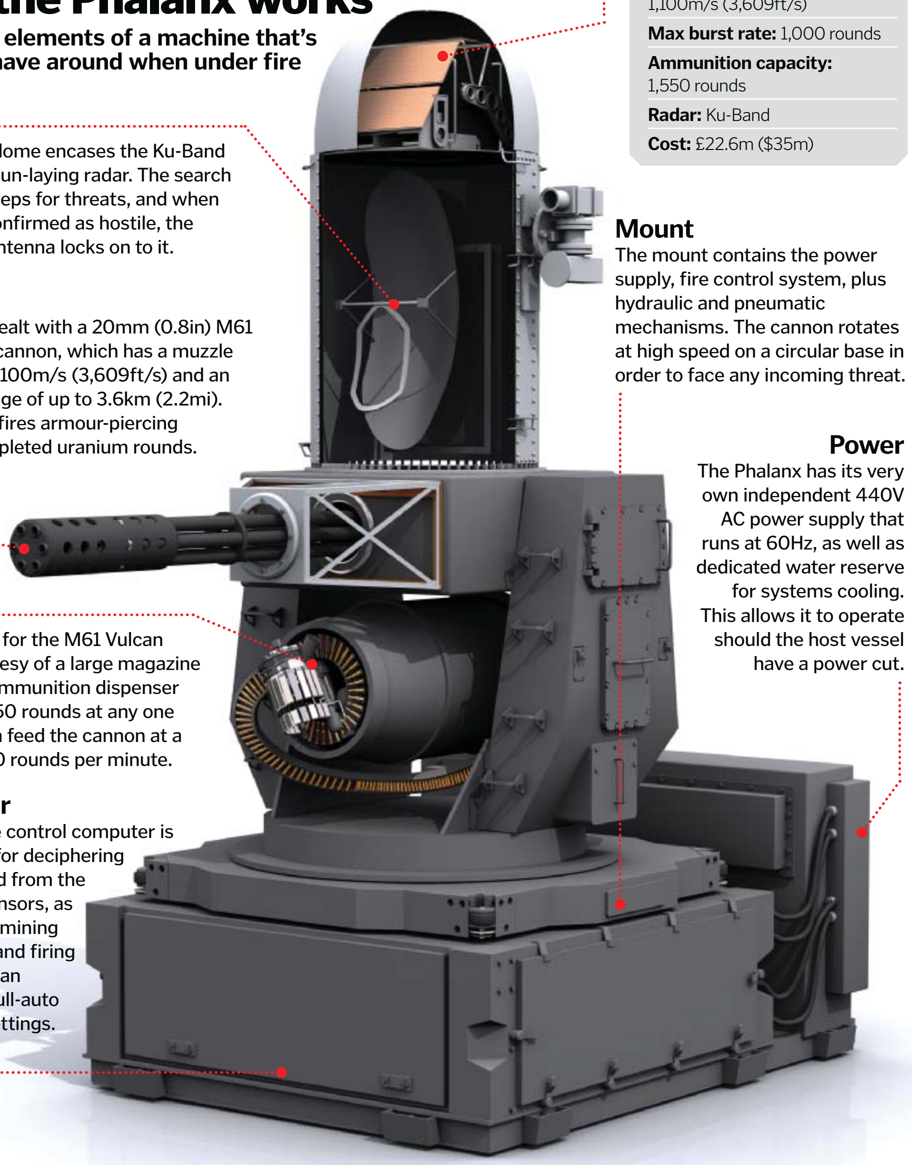
The Phalanx is mounted to a variety of vessels in the US Navy, where it is tasked with defending every class of surface combat ship. This defence comes courtesy of thousands of armour-piercing tungsten and depleted uranium rounds, which are projected from the autocannon at 1,100 metres (3,610 feet) per second. For perspective, that's the equivalent of travelling the length of Manchester United's football pitch about ten times in a second!

The rounds' trajectories are dictated by a built-in fire control system. This central computer can instantly calculate the probability of the Phalanx taking a target out, as well as what fire rate and pattern is needed. The control system is fed data from the two antennas of the Ku-Band radar, with a wide aperture search antenna picking up incoming threats, and a gun-laying antenna taking care of the fine, narrow aperture object targeting.

In addition to providing defence against incoming missiles and shells, the Phalanx can also operate against more traditional targets – such as small surface vessels – thanks to the inclusion of a forward-looking infrared (FLIR) sensor. This tech detects infrared radiation – ie heat signatures – and helps the Phalanx deal out massive damage to enemy ships.

How the Phalanx works

The major elements of a machine that's handy to have around when under fire



Sensors
Certain Phalanx systems come installed with forward-looking infrared (FLIR) sensors to detect surface vessels and approaching missiles.

Radar
A tubular radome encases the Ku-Band search and gun-laying radar. The search antenna sweeps for threats, and when a target is confirmed as hostile, the gun-laying antenna locks on to it.

Gun
Damage is dealt with a 20mm (0.8in) M61 Vulcan autocannon, which has a muzzle velocity of 1,100m/s (3,609ft/s) and an effective range of up to 3.6km (2.2mi). The cannon fires armour-piercing tungsten/depleted uranium rounds.

Drum
Ammunition for the M61 Vulcan comes courtesy of a large magazine drum. This ammunition dispenser can hold 1,550 rounds at any one time and can feed the cannon at a rate of 4,500 rounds per minute.

Computer
A central fire control computer is responsible for deciphering data received from the radar and sensors, as well as determining hit chances and firing patterns. It can operate on full-auto or manual settings.

Mount
The mount contains the power supply, fire control system, plus hydraulic and pneumatic mechanisms. The cannon rotates at high speed on a circular base in order to face any incoming threat.

Power
The Phalanx has its very own independent 440V AC power supply that runs at 60Hz, as well as dedicated water reserve for systems cooling. This allows it to operate should the host vessel have a power cut.

The statistics...

Phalanx CIWS 1A/B

Height: 4.7m (15.4ft)
Weight: 6,200kg (13,600lb)
Elevation: -25° to 85°
Gun: 1 x 20mm (0.8in) M61 Vulcan autocannon
Muzzle velocity: 1,100m/s (3,609ft/s)
Max burst rate: 1,000 rounds
Ammunition capacity: 1,550 rounds
Radar: Ku-Band
Cost: £22.6m ($35m)

How does the Phalanx stack up to the competition?

AK-630
The Russian equivalent of the Phalanx, the AK-630 is a naval close-in weapon system that boasts a six-barrelled 30mm (1.2in) Gatling cannon capable of firing 10,000 rounds per minute.

Goalkeeper
The Dutch counterpart of the Phalanx, the Goalkeeper is designed to shoot down missiles and ballistic shells. It sports a 30mm (1.2in), seven-barrelled cannon with a muzzle velocity of 1,109m/s (3,638ft/s).

DARDO
The Italian-made DARDO (which translates as 'dart') is a close-in weapon system equipped with two massive Bofors 40mm (1.6in) high-explosive shell firing autocannons.

Scream

if you want to go

Ultrafast

Who decided speed was just for the jetsetters? At Three, we think everyone should feel the rush of wind between their thumbs. So we're revving up our entire network, adding some extra g-force, without charging a hefty premium. That's ultrafast, without the ultra pricey.

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"Bone tends to absorb the X-rays, while organs and flesh are less capable of blocking them"

CT scanners explained

What is computed tomography used for and how does it image the inside of our bodies?

A CT, or CAT, scanner is a diagnostic device commonly used in hospitals to evaluate head injuries, abdominal problems and stroke victims. It stands for computed tomography, or computed axial tomography, as the image data is processed and resolved by a sophisticated computer system.

The CT scanner uses a low-dose X-ray beam that traverses a select area of the body in an axial (horizontal) or transverse (perpendicular) plane. The machine itself features a large cavity where the patient is positioned and through which the X-rays pass. Tubes emit X-rays on one side of the scanner, while a special detector located opposite picks up the beam. Similar to a standard X-ray machine, they enter the body and are either soaked up or travel straight through, depending on the body part. For example, bone tends to absorb the rays resulting in an opaque silhouette, while organs and flesh are less capable of blocking them and so yield more translucent results.

Today's CT machines rotate the X-ray tubes and detectors around the patient to get multiple cross-sections, enabling the computer to create high-detail 3D images that, in some scans, can even be manipulated in real-time.

Image processing

As soon as the raw data has been collected the computer can process images from it. Sometimes a simple cross-section is all that is required, but modern CT scanners are quite capable of layering multiple 'slices' through the human body, stacking them up to create a dynamic pass-through of the subject. Depending on the evaluation, the software compiling the data can create an image via a different plane simply by slicing through the body at another angle. This is useful in images of the spine, for example, where axial shots only show individual vertebra but an orthogonal slice through can reveal the vertebrae and their discs in their entirety. 3D images can also be rendered if needed. Surface rendering can colour different tissue types but can't show internal structures, volume rendering is used to show tissue density, and image segmentation is utilised to remove any unwanted components from the shot.

CT evolution

Whereas radiography started way back in 1895 with Wilhelm Röntgen's X-ray imaging device, computed tomography came much later. It hinged, of course, on the birth of the computer and – significantly – a computer with enough power. CT scanners were invented in 1972 by Godfrey Hounsfield, an engineer for EMI Laboratories, and Allan Cormack of Tufts University, MA. The first machines appeared in hospitals in 1974 and could only scan the head, taking several hours to create a single 'slice' of raw data and then days for the computer to actually generate an image. A modern CT scanner, meanwhile, can analyse someone's chest and create an image in less than a minute.

CT scans are also used in archaeology, like this scan of a Peruvian mummy showing its muscles and bones

"The tEODor is equipped with an arm-like manipulator, sensors and a camera on a boom"

Bomb-disposal robots

HIW takes a look at the Cobham tEODor to learn how these robots are configured to disarm explosives

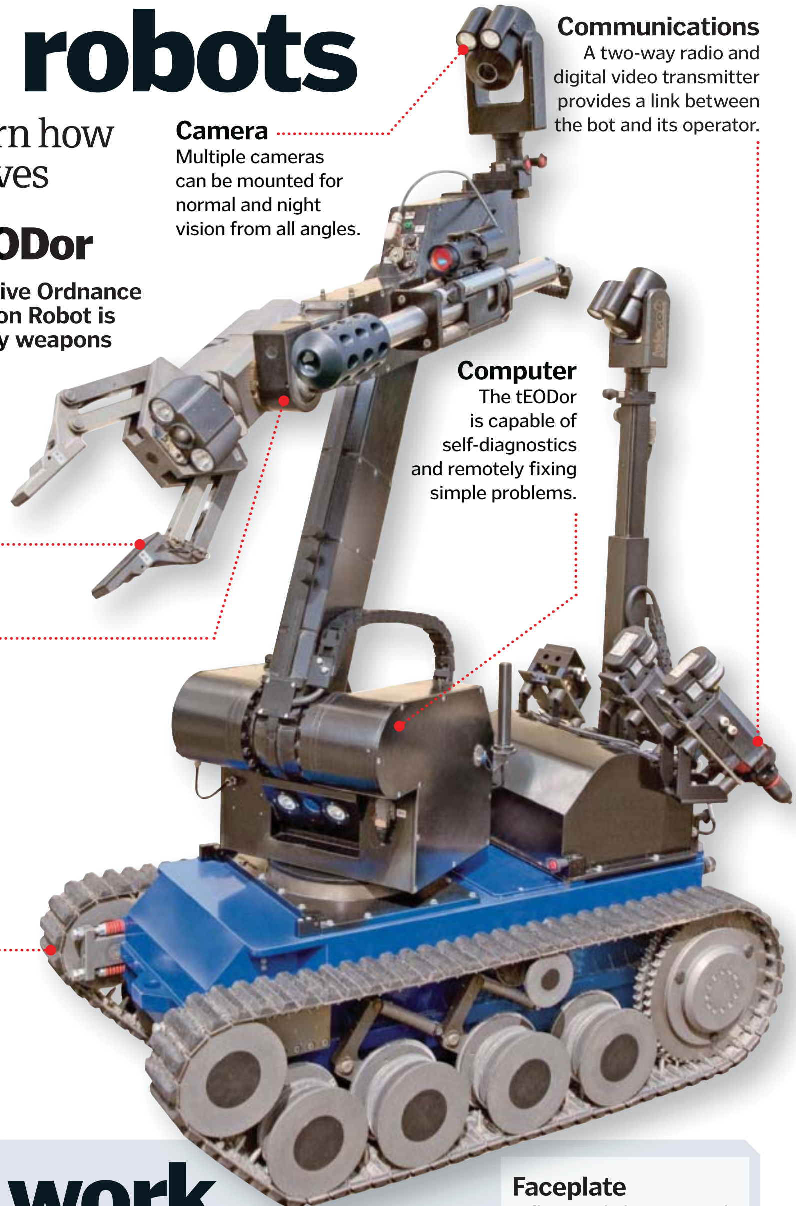
Bomb-disposal, or explosive ordnance disposal (EOD), robots are one of the many tools a technician might use to disarm dangerous weapons. Besides the human cost of losing a bomb technician in the field, training a bomb-disposal officer is significantly more expensive than buying an EOD robot. As a result, maintaining a safe distance from a potential bomb is of paramount importance and only in extreme situations will the technician enter the blast range and put their hands on the device themselves.

One of the most widely used bomb-disposal robots today is the Cobham tEODor (pictured). The base robot is a twin-track vehicle with a host of military applications, but the standard tEODor is the bomb-disposal specialist. It's equipped with an arm-like manipulator, sensors and a camera on a boom for enabling the operator to remotely disarm ordnance and improvised explosive devices (IEDs).

In most cases, the technician working with the robot will sit at a safe distance with the control station. This is a laptop-like device which consists of a monitor showing the robot's point of view as well as its surroundings, plus a joystick and control panel to manipulate the arm and manoeuvre the tracks.

Meet the tEODor

How the Telerob Explosive Ordnance Disposal and Observation Robot is primed to defuse deadly weapons



How door handles work

We let you in on the engineering of the device we couldn't leave the house without

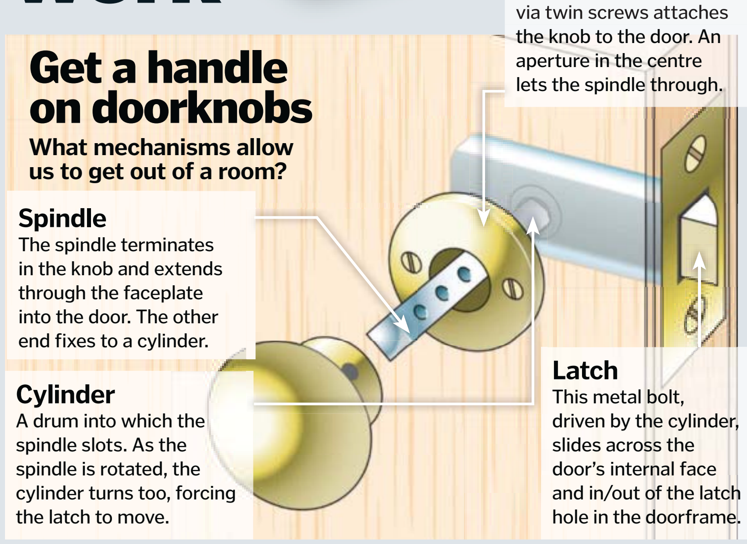
A door handle controls a door by manipulation of a latch – a mechanical fastener that joins two or more objects together. In this case, a latch connects the door with its frame and tends to embody a sliding bolt installed in the door and a receptacle in the frame.

The latch's position is determined by the handle – which can take many forms including knob and lever. This is connected to the latch via a spindle and cylinder. When the handle is pulled/rotated, the action is carried by the spindle into the cylinder, which turns clockwise or anticlockwise depending on its orientation.

The movement of the cylinder causes the attached bolt to be forced across the door's internal face, sliding in/out of the frame's latch receptacle allowing the door to be either opened or shut.

Get a handle on doorknobs

What mechanisms allow us to get out of a room?



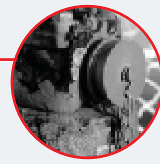
KEY DATES
HYDRANT HISTORY

~1700 Wooden water-filled pipes begin to line the streets of London after the Great Fire of 1666.

1801 US engineer Frederick Graff Sr invents the first pillar hydrant at the start of the 19th century.

1838 A patent is filed for a more advanced hydrant. It is one of the first wet type varieties.

1870 Metal fire hydrants overtake wooden ones as the most frequently installed type.



1882 The now common Storz hosepipe hydrant connector is invented by Carl August Storz.

DID YOU KNOW? *In the US, it is illegal to park a vehicle within 4.5m (15ft) of a fire hydrant*

Fire hydrants in focus

How do these colourful posts grant access to water in an emergency?

Fire hydrants, or plugs, are active protection devices that allow emergency services such as the fire brigade to quickly tap in to a local water supply.

A typical above-ground pillar hydrant consists of a cylindrical, capped and valved drum standing proud of the pavement. This drum acts as a portal between the below-surface mains pipeline and the emergency service's hoses, governing the rate of flow.

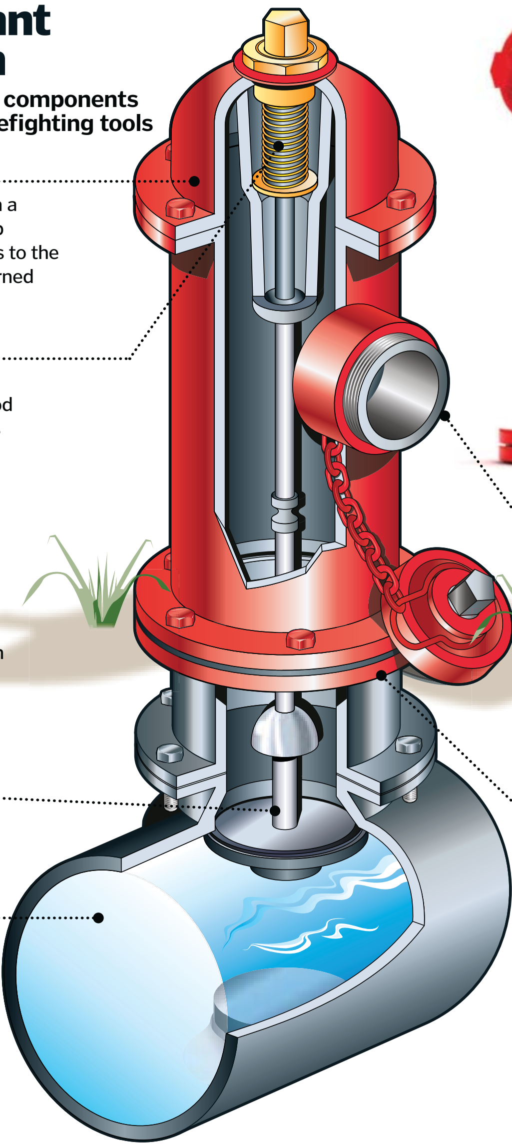
Water is accessed via the hydrant with a special five-sided wrench, which allows the valve covers to be removed. Once firefighting hoses have been connected to the valves – of which there are typically three (one large main opening and two smaller, side-mounted subsidiary ones) – water is drawn up through manipulation of what is commonly known as the stem nut. This nut acts in much the same way as domestic tap handles, allowing water to be streamed slower/faster or stopped.

As hydrant water is sourced from low-pressure municipal sources – typically around 3.5-5.6 kilograms per square centimetre (50-80 pounds per square inch) – to gain the adequate propulsion it must be filtered through pumps, which are located on emergency vehicles like fire engines. This dramatically increases the water's pressure, allowing for safer and more effective long-distance spraying.

There are two main types of hydrant: dry barrel and wet barrel. Dry-barrel hydrants are the more common and are so named as they don't allow water to stay in the upper section (ie the drum above the ground). This prevents the water freezing when the temperature drops.

Pillar hydrant breakdown

Learn about the core components of these everyday firefighting tools



Cap
The hydrant is topped with a dome-shaped cap. The cap protects and allows access to the stem nut, which can be turned with a tailored wrench.

Spring
A compression spring surrounds the operating rod and compresses when it is engaged. It returns to a decompressed state when the hydrant is not in use.

Rod
An operating rod is activated by manipulating the stem nut, which in turn opens the water inlet valve, allowing water to flow in from the mains.

Supply
Water is drawn up through the hydrant from the region's municipal water supply. As it has a relatively low pressure, the water's pressure is increased by pumping units within a fire engine prior to spraying.

Fire hydrants are generally brightly coloured or coated with reflective paint so that they're easy to spot

Outlet
This is the exit point of the hydrant from the mains water supply. Hoses are connected to the end and then fixed with a slot lock.

Lock
The upper cylindrical drum section is secured to the subsurface section via a rotational locking mechanism.

"They were originally designed for making POV surfing videos but now cover a range of extreme sports"

How action cameras record on the go

What makes a cutting-edge wearable camera tick? How It Works probes inside the GoPro HERO3…

HERO3 exploded

We take a peek inside GoPro's latest mountable action-cam

Backing
The waterproof cover for the battery compartment.

Speaker
The speaker and the button assembly are attached to the back.

Housing
The innards are kept in toughened plastic that is waterproof to 60m (180ft).

Battery
This 1,050mAh lithium-ion rechargeable cell has a pull-tab for easy release.

GoPro has been making wearable cameras for nearly a decade now, since its debut 35-millimetre (1.4-inch) film camera system was launched in 2004. They were originally designed for making point-of-view surfing videos but have now expanded to cover a huge range of extreme sports and pursuits, including diving, skydiving, motocross and more or less anything where a hands-free video recorder is required.

The principal features of these cameras have always been that they are small and lightweight, shockproof and waterproof, and compatible with a host of mounts that enable them to be securely attached to the user and get up close to the activity. They also use multimedia technology that allows for crisp audio and video capture at speedy frame rates.

There are three versions of the GoPro HERO3, all of which can record 1080p-resolution video at a minimum 30 frames per second, with the top-end Black edition capable of the latest 4K video at 15 frames per second. The standard photo mode can snap 5-12-megapixel shots at regular intervals of 2-60 seconds, although it differs from standard digital cameras in that there is no zoom lens or viewfinder. In any case the GoPro HERO is designed to be activated and left to its own devices, rather than manually operated, enabling the user to focus their full attention on the extreme sport at hand.

Finally, the vital mounting components comprise a comb joint, nut and bolt, and the GoPro HERO3 also boasts mounts tailored especially for handlebars, roll bars (for sports cars), helmets and a chest harness.

DID YOU KNOW? *Felix Baumgartner also holds the world record for the lowest BASE jump, at 29m (95ft)*

Daughterboard
This has an extra port for a microSD as well as proprietary GoPro accessories like the 3D HERO system.

Image sensor
This Sony-made IMX117 sensor detects up to a 12MP resolution at 35 fps.

LCD
This simple display is used to show image settings like fps and resolution, rather than display images.

Motherboard
The main camera chipset includes CPU, integrated flash memory (for storage), 512MB RAM, as well as Bluetooth and USB controllers.

Lens
This is the ultra-sharp, aspherical glass lens that lends a fisheye view to both photos and videos.

A real hero: Felix Baumgartner

Easily the GoPro HERO3's most prominent media use to date was in the Austrian skydiver Felix Baumgartner's record-breaking Red Bull Stratos freefall. On 14 October 2012, Baumgartner took a specially designed helium balloon into Earth's stratosphere, setting an altitude record at just under 39 kilometres (24 miles) for a manned balloon flight (the edge of space, incidentally, is found at 100 kilometres/62 miles). He then jumped out of the balloon and set the world record for the highest parachute jump and, during the same jump, achieved a speed of 1,357.6 kilometres (843 miles) per hour for the greatest human freefall velocity ever achieved.

The entire event was recorded using five GoPro HERO3 cameras, all strapped to various parts of Baumgartner's body and positioned in strategic point-of-view angles. Naturally, they caught the moment he broke the sound barrier – the first person ever to do this in freefall.

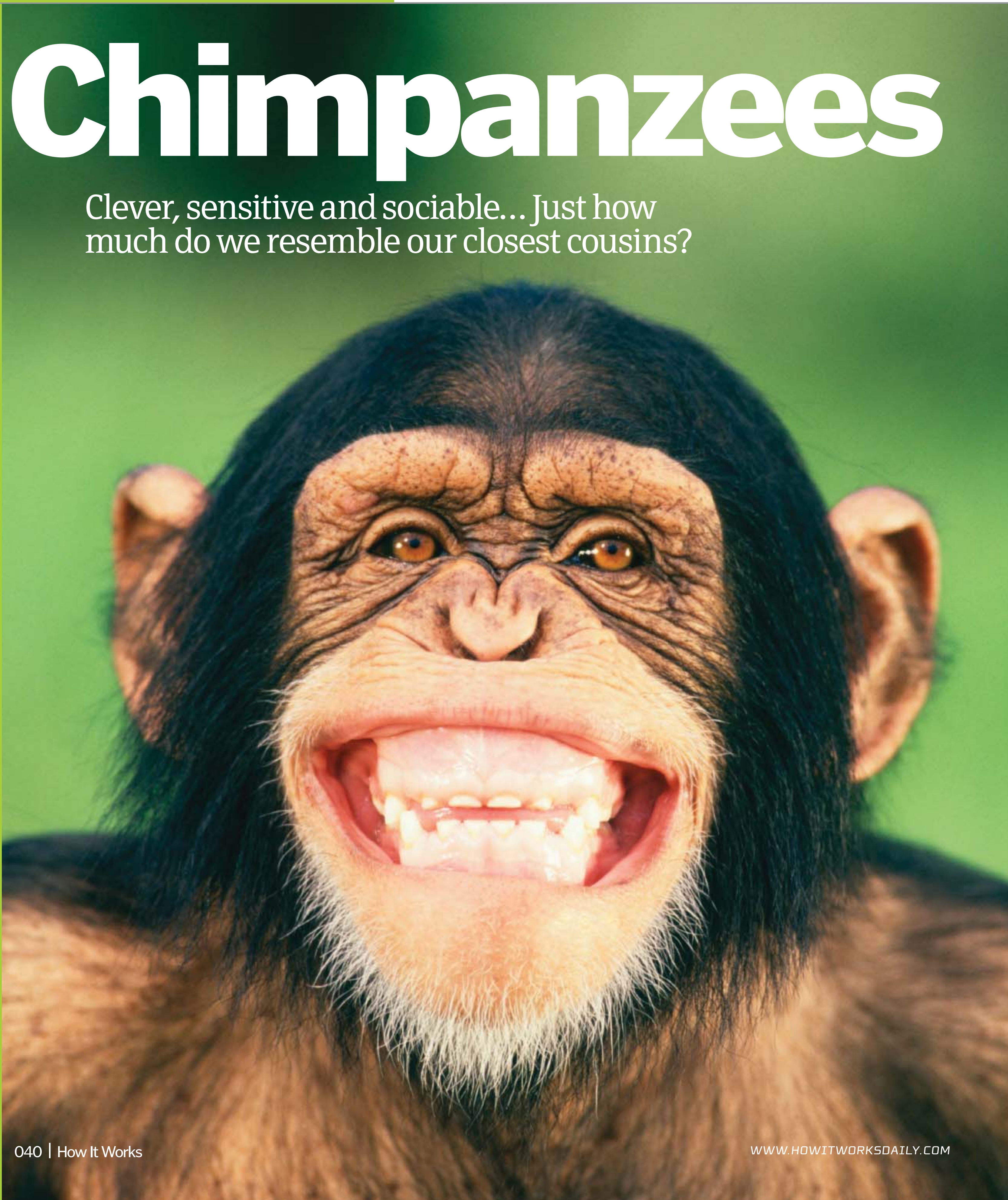
Another dimension

GoPro has a number of accessories that enhance a multimedia capture device of this kind in the field, but one of the more sophisticated and interesting systems has to be the 3D HERO.

This is essentially a housing that lets you combine two GoPro cameras together, side by side. Once in place, either end of a cable plugs into the rear port of each of the cameras to synchronise video, photos and sound. As the apertures of each camera are separated by no more than a couple of centimetres (like our eyes), the data captured is very similar but still differs slightly. It's just enough for a bespoke piece of software to stitch the video or still images together to create a three-dimensional result. This can then be viewed with a pair of 3D anaglyph glasses. Because the 3D anaglyph data is the result of two 2D images, both 2D and 3D footage can be recorded simultaneously.

Chimpanzees

Clever, sensitive and sociable… Just how much do we resemble our closest cousins?



HEIGHT 1-1.7m | WEIGHT 26-70kg | REPRODUCTIVE AGE (YEARS) 13-16

TOP SPEED 40km/h | LIFE SPAN (YEARS) 40-60 | GESTATION PERIOD 8 months

DID YOU KNOW? *In the Seventies Jane Goodall observed a war between chimp communities that lasted four years*

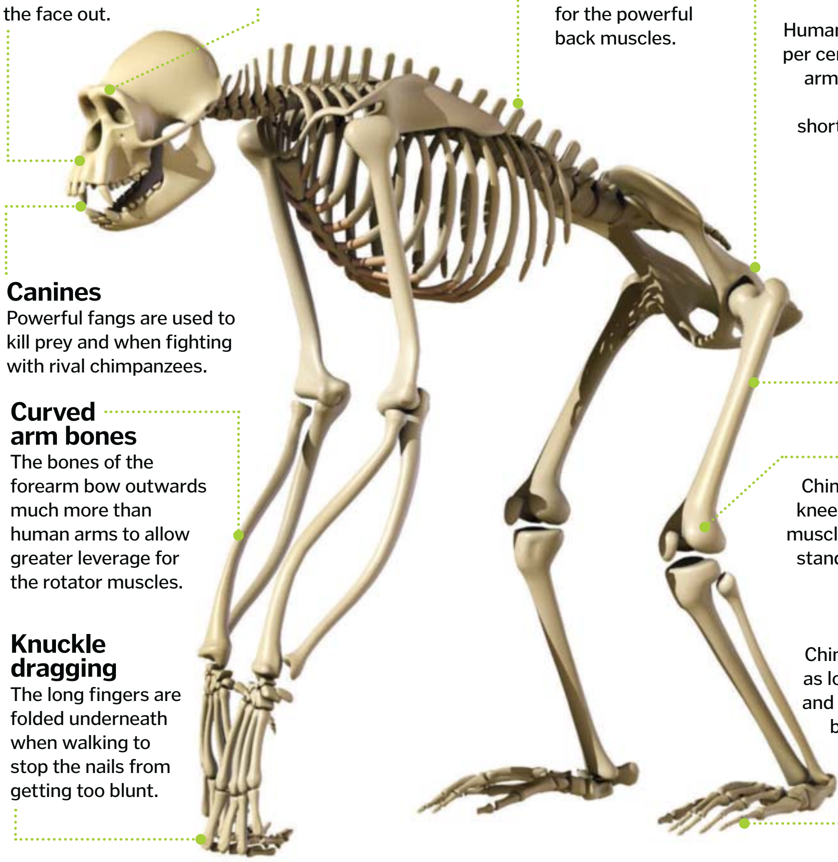
Chimpanzees, and their cousins the bonobos, are our closest evolutionary relatives. That doesn't mean that we are descended from chimpanzees. Humans and chimps share a common ancestor from about 4 million years ago. That's when the populations split, with humans evolving from one branch and the other becoming the common ancestor of chimpanzees and bonobos. These two species only separated about a million years ago, probably when the Congo River formed and isolated the populations. We share at least 90 per cent of our DNA with chimpanzees, and possibly as much as 99 per cent. The fact that we still look so different is partly because a lot of the genes that we *don't* share are the ones that control the behaviour of the genetic regulation mechanisms themselves. This means that even quite small genetic differences can have a big impact on the way that our bodies develop and grow.

Chimpanzees would be almost as tall as us if they stood fully upright, but their bodies are designed for quite a different posture. Chimps spend a lot of their time in the trees and have long, powerful arms that make it easy to swing from branch to branch. Chimpanzees can stand and walk upright, but their skeleton isn't adapted to do this easily. Their thighbones slope outwards more than ours and the knee joints don't let their legs fully straighten. This forces chimps to adopt a side-to-side waddling gait that is slower and less stable than ours. On the other hand, having longer arms and a spine that doesn't curve into an 'S' shape makes it easy to walk on all fours and look ahead at the same time. Chimps stand upright to walk when carrying something, or to make themselves appear larger and more threatening, but they prefer knuckle-walking most of the time.

Chimpanzees don't only eat bananas and fruit as you might expect. While fruit and plants do make up the bulk of their diet, they aren't fussy eaters and will also dine on insects, eggs and meat. They hunt in small groups and their powerful jaws and sharp teeth mean they are quite capable of catching and killing small deer and antelope. Chimpanzees aren't quite at the top of their food chain though – leopards are their number two predator, after humans. But leopards don't always have things their

Anatomy of a chimpanzee

They may be close relatives, but these apes are adapted differently to suit their own environment



Protruding face
The jaw is larger and more powerful than ours, so it pushes the face out.

Eyebrow ridges
Thick bone protects the eyes and extends above the relatively small braincase.

Vertebra
The tall bones on the spine provide wide attachment points for the powerful back muscles.

Pelvis
The chimpanzee pelvis is long and narrow because it doesn't need to constantly support the extra load of standing upright like us.

Short leg
Human legs are about 40 per cent longer than their arms, while chimp legs are actually a little shorter than their arms.

Canines
Powerful fangs are used to kill prey and when fighting with rival chimpanzees.

Curved arm bones
The bones of the forearm bow outwards much more than human arms to allow greater leverage for the rotator muscles.

Knee
Chimps can't lock their knees so they must use muscles whether they're standing or on all fours.

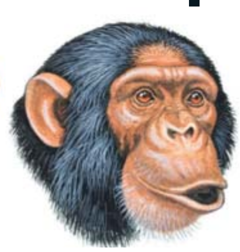
Knuckle dragging
The long fingers are folded underneath when walking to stop the nails from getting too blunt.

Long toes
Chimp toes are almost as long as their fingers and have an opposable big toe for gripping.

Reading the mind of a chimp

Chimpanzees have 23 different muscles that control facial expressions (the mimetic muscles), compared with 43 in most humans. That's still more than most other primates though and this allows chimps to have a much more subtle repertoire of expressions. Just as humans can smile with their mouth but not with their eyes, it's important to look at the whole of a chimpanzee's face if you want to correctly interpret how it is feeling.

Friendly
The classic teeth bared expression is an almost universal indication of fear in the animal world. In the more complex societies of chimps, however, it is more a sign of appeasement or benign intentions. If this seems strange, then consider our own signal of friendship: the smile.



Submissive
Pursing the lips is a way to demonstrate that he defers to a dominant male. This expression is also used to beg for food from another chimp, in much the same way that humans might make a praying gesture to either beg or show submissiveness.

Conflicted
Pressing the lips together and blowing so the lips bulge outwards is a sign of conflict in the mind of the chimpanzee. Together with a frown, it indicates anger, but the raised eyebrows of this chimp suggest that he is feeling confused instead.

"The brain of a chimpanzee is less than a third the size of ours, but they show a high degree of intelligence"

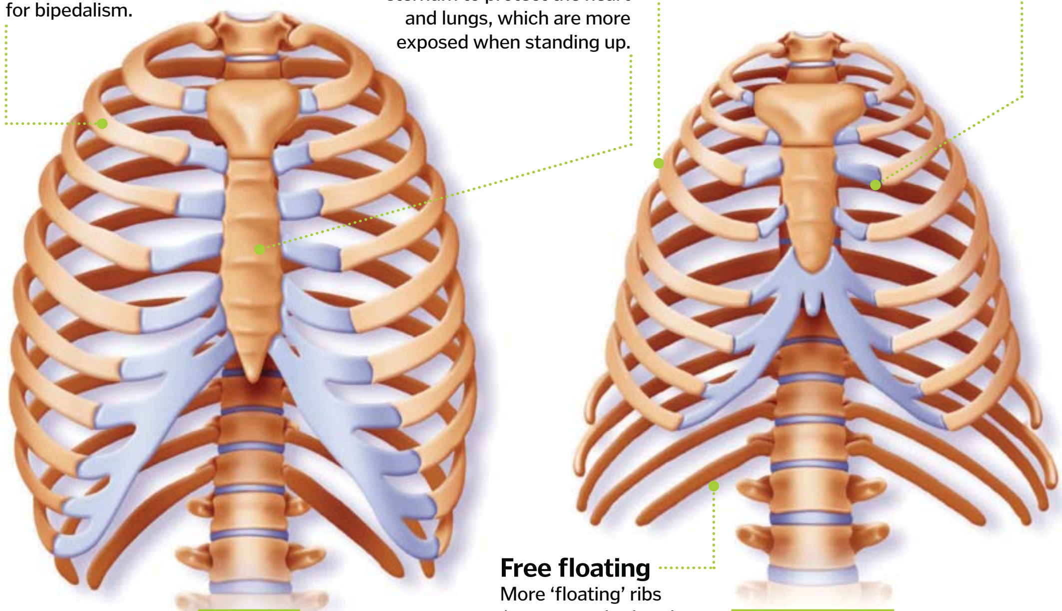
own way; chimpanzees use sticks to defend themselves and, when acting co-operatively, can often kill the big cat. Chimps will always try to run from humans, but if cornered they can be very dangerous and have been known to kill people by grabbing them by the feet and dashing them against the ground.

The brain of a chimpanzee is less than a third the size of ours, but nevertheless they show a high degree of intelligence, even compared to other great apes. Chimpanzee females whose child has died have been observed to carry the body around in an apparent display of mourning. And when they encounter other animals they sometimes behave in ways that seem purposely cruel or kind, rather than simply hunting or fleeing. For example, chimps will sometimes kill a tortoise by forcing a stick into it, but they don't then eat the tortoise. Is this just for sport? On other occasions chimps have been seen feeding tortoises, almost as if they were pets. Bill Wallauer, a videographer at the Gombe National Park in Tanzania recounts that when chimpanzees encounter a python, they gather round to watch it, apparently torn between fear and fascination. A python is normally neither food nor a threat to a chimpanzee and yet they can watch the snake for up to half an hour, touching and hugging one another for reassurance while they do, just like we would during a scary movie.

Their similarity to us means that chimpanzees have been used as research subjects to test drugs and medical procedures. Only the USA and Gabon in Africa still perform medical research on chimpanzees and most of those used in the US have now been retired to sanctuaries. In the past though they were used quite widely; indeed, 400 chimpanzees were bred in US labs in the Eighties and Nineties for HIV research alone. Two chimps were even sent into space as part of the early US space programme. Ham, a three-year-old chimp, was the first in 1961. Although he touched down safely, he didn't appear to enjoy the experience, refusing to stay in the flight seat for photos.

A dig in the ribs

Humans and chimps have quite distinct ribcages to cope with different postures



How do we compare?

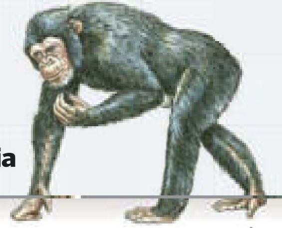
Chimpanzee
Face shape: Jaw and brow protrude forwards
Length of teeth: Long with powerful canines
Brain size: 400cc (24.4ci)
Arm length: Arm span 1.5 times height
Knuckle walker?: Yes
Big toe: Opposable like a thumb

Australopithecine
Face shape: Jaw and brow protrude forwards
Length of teeth: Small and even
Brain size: 450cc (27.4ci)
Arm length: Shorter
Knuckle walker?: No
Big toe: Human-like, not prehensile

STRANGE BUT TRUE
IN THE BLOOD

What's special about a chimp's white blood cells?

A They are tiny **B** They are blue **C** They prevent malaria

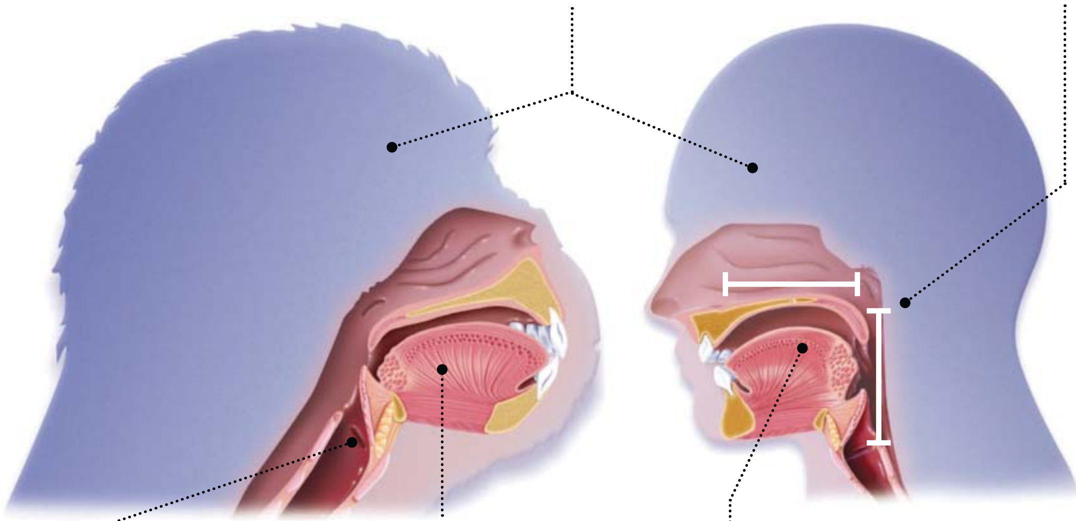


Answer:
Chimpanzees have a different kind of white blood cell that protects them from diseases like malaria and HIV. However, many nations have now banned lab testing on chimps due to their close relation to humans.

DID YOU KNOW? Chimps have big 110g (4oz) testes as females have many partners, so males need to be able to deliver!

Chimp chat

Chimps use vocal communication but can't form human speech. The reason lies with the structure of their airway…



Broca's region
Both humans and chimps have the same structure in the brain called Broca's area, which is active when communicating.

Evenly proportioned
Humans have roughly the same-sized horizontal and vertical sections of the vocal tract. This means it's easier to make precise vowel sounds.

Face forward
The elongated face of the ape means that the tongue is almost entirely confined to the mouth.

Larynx
Chimps and newborn humans have a raised larynx, which allows simultaneous swallowing and breathing, but a smaller vocal range.

Tongue
Human tongues extend partly into the pharynx, allowing for a wider range of sounds to be produced.

The social order

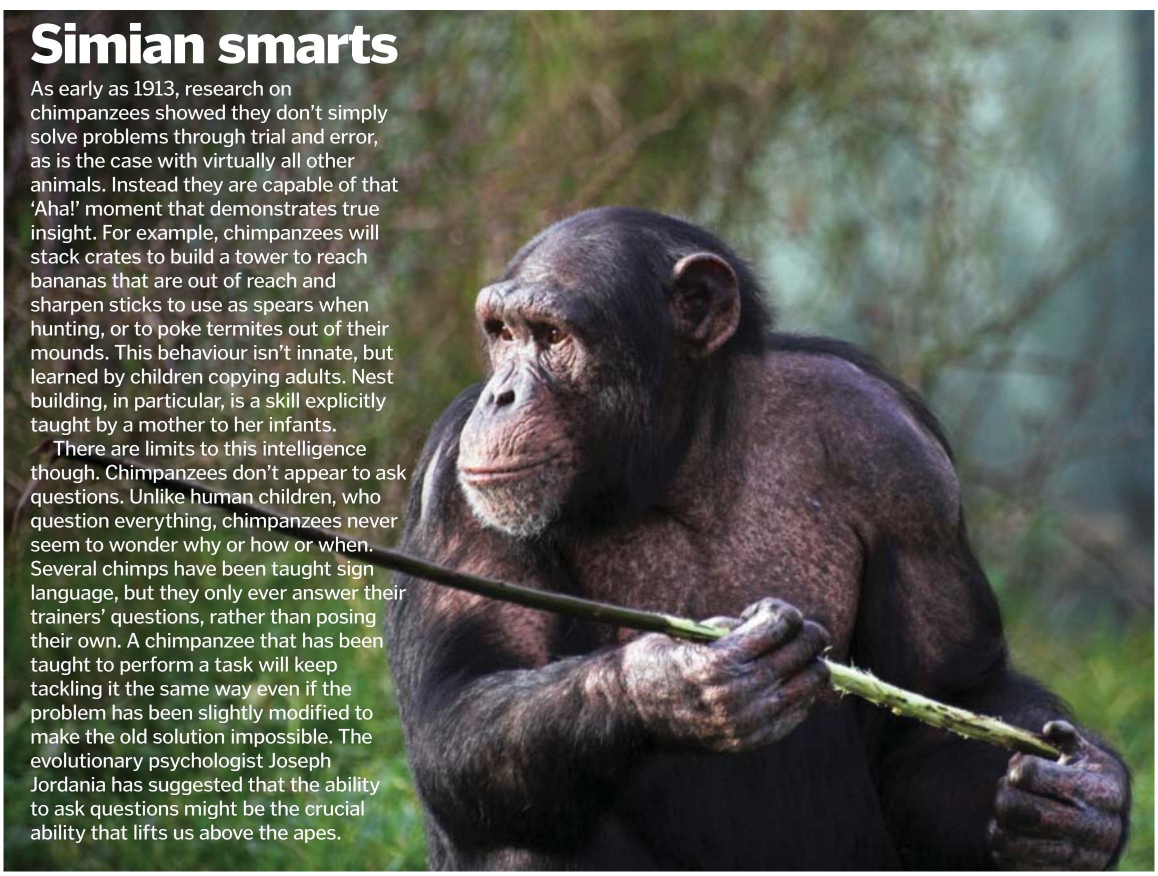
Chimpanzees live in communities of 40-60, but they travel and hunt in smaller troops of ten or so which are constantly changing as individuals move between troops. Males and females each have their own hierarchies. The males have a single 'alpha' in charge of the whole community. This is partly decided by age and strength, but politics plays a role too. Alpha males that are able to form lots of alliances are more likely to hold on to their position and, conversely, females will sometimes conspire to topple an unpopular male in favour of another who would make a better leader. Mothers have extremely close bonds with their children – especially their daughters. Social status in chimpanzee females is partly hereditary with the daughters of high-status females having disproportionately higher status of their own. Within a community social grooming and food sharing helps to keep the group together, but reactions to other chimp communities can be quite hostile.

Modern human
Face shape: Flat, with a distinct chin
Length of teeth: Small and even
Brain size: 1,300cc (79.3ci)
Arm length: Shortest – arm span equals height
Knuckle walker?: No
Big toe: Not prehensile

Simian smarts

As early as 1913, research on chimpanzees showed they don't simply solve problems through trial and error, as is the case with virtually all other animals. Instead they are capable of that 'Aha!' moment that demonstrates true insight. For example, chimpanzees will stack crates to build a tower to reach bananas that are out of reach and sharpen sticks to use as spears when hunting, or to poke termites out of their mounds. This behaviour isn't innate, but learned by children copying adults. Nest building, in particular, is a skill explicitly taught by a mother to her infants.

There are limits to this intelligence though. Chimpanzees don't appear to ask questions. Unlike human children, who question everything, chimpanzees never seem to wonder why or how or when. Several chimps have been taught sign language, but they only ever answer their trainers' questions, rather than posing their own. A chimpanzee that has been taught to perform a task will keep tackling it the same way even if the problem has been slightly modified to make the old solution impossible. The evolutionary psychologist Joseph Jordania has suggested that the ability to ask questions might be the crucial ability that lifts us above the apes.



> "A dog's nose has so many olfactory receptors that its sense of smell is 1,000 times more acute than ours"

What is diamond dust?

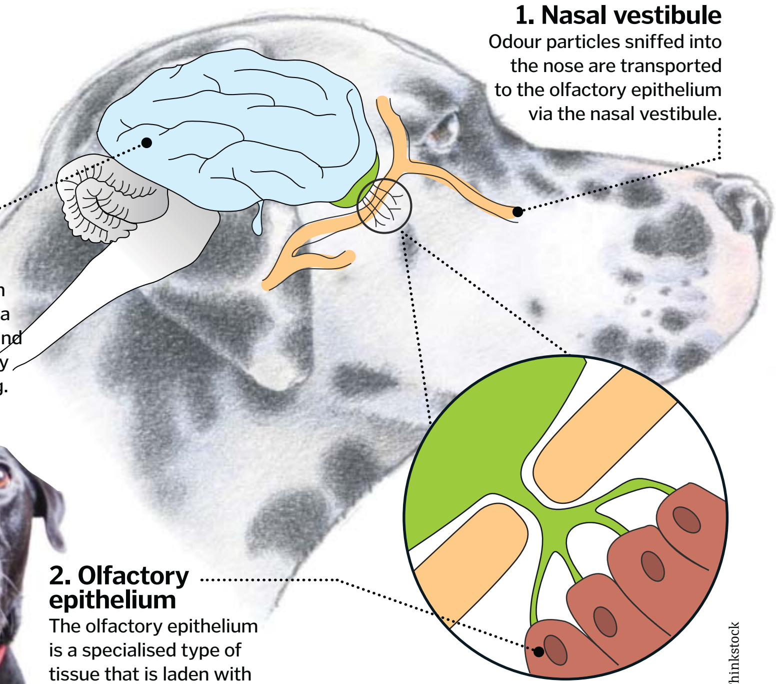
Here's a clue: this atmospheric effect has nothing to do with precious gems

Diamond dust is the common metaphor used to describe a cloud of minuscule ice crystals at ground level. It can form naturally under fairly specific conditions in any part of the world where the temperature is below freezing. The tiny ice crystals that characterise diamond dust appear when there's a thermal inversion and the warmer air above the ground mixes with the colder air below (cooler air is usually above). Water vapour in the warmer air increases the relative humidity at the cold surface and, if this increase is large enough, diamond dust occurs. Unlike fog, which is thousands of water droplets in the air, diamond dust rarely affects visibility and can often create vivid optical effects. Haloes around the Sun, known as parhelia, and other stunning phenomena occur in the presence of diamond dust as the defined geometric shapes of the ice crystals refract light in various directions.

How do dogs smell?

Ever wondered why canine noses are so good at finding food? HIW sniffs out the answer

Man's best friend is famous for its sense of smell. In canines this consists of a nasal vestibule and olfactory epithelium. The former channels odour-rich particles to the latter, with the epithelium supporting millions of receptor cells that absorb the odour's chemical composition patterns and then transports them to the brain for interpretation. Indeed, an average dog's nose has so many olfactory receptors that its sense of smell is 1,000 times more acute than ours. And why are dog noses wet? Well, they generally have damp snouts for two reasons. Firstly, a wet nose is better for smelling. The moisture comes from a layer of mucous that thinly covers the surface, trapping and soaking up scent particles. The dog can therefore naturally sniff in the smell as it radiates off the nose, or lick it to taste the odour. The second reason is that it is one of the few parts of the body where dogs can excrete sweat.



5 TOP FACTS
OSTRICHES

Over-egged
1 Ostrich eggs are usually 15 centimetres (5.9 inches) long, weigh up to 1.4 kilograms (3.1 pounds) and take 40 days to hatch. A single ostrich egg is equivalent to 24 chicken eggs.

Big bird
2 While the ostrich is the largest living bird today, the biggest ever to have lived was the elephant bird of Madagascar, which grew to a staggering three metres (9.8 feet) tall.

Daddy day care
3 In the ostrich world it's the males who raise the chicks once they are old enough to leave the nest. Crèches of up to 50 youngsters are nurtured by a single alpha male.

Raising the alarm
4 Ostriches are often the first on the savannah to alert others of impending danger. When threatened ostriches can be aggressive and lash out with their powerful legs.

Community matters
5 Ostriches from the same herd lay eggs in a communal nest scraped out of the ground. The eggs are incubated by a dominant hen who keeps her eggs safest in the centre.

DID YOU KNOW? At 5cm (2in) across, an ostrich's eyeball is bigger than its brain

How do ostriches sprint?

Find out why the largest bird on Earth is also the Usain Bolt of the avian kingdom

A member of the ratite group of birds who have weak wing muscles and so cannot fly, the ostrich is the biggest bird on the planet today. Found mainly in the semi-arid regions of central and southern Africa, where lions, leopards and hyenas are constantly on the prowl, ostriches have learned to outrun their enemies.

Ostriches have the speed to evade most African predators, and when frightened they can sprint away from danger at up to 72.5 kilometres (45 miles) per hour. They can also run over longer periods of time at slower speeds – say, for 20 minutes at 48 kilometres (30 miles) per hour. While speed is clearly an ostrich's main advantage, when trapped they are not entirely defenceless as they can use their strong legs to land a mighty blow on a would-be attacker. And their two-toed feet feature a pretty nasty ten-centimetre (four-inch) claw that can also inflict a lot of damage.

So what enables this nomadic, social bird to take off at such impressive speeds? Those unique toes we mentioned are also key to the creature's agility as – together with their strong leg muscles – they maximise speed by ensuring minimal contact is made with the ground. The ostrich is the only bird with two toes and it's the inner of the two that is the most important. This digit is longer, which assists the bird in pushing off with its feet, and it also features that potentially lethal claw. This foot layout helps to support the weight of this hefty bird.

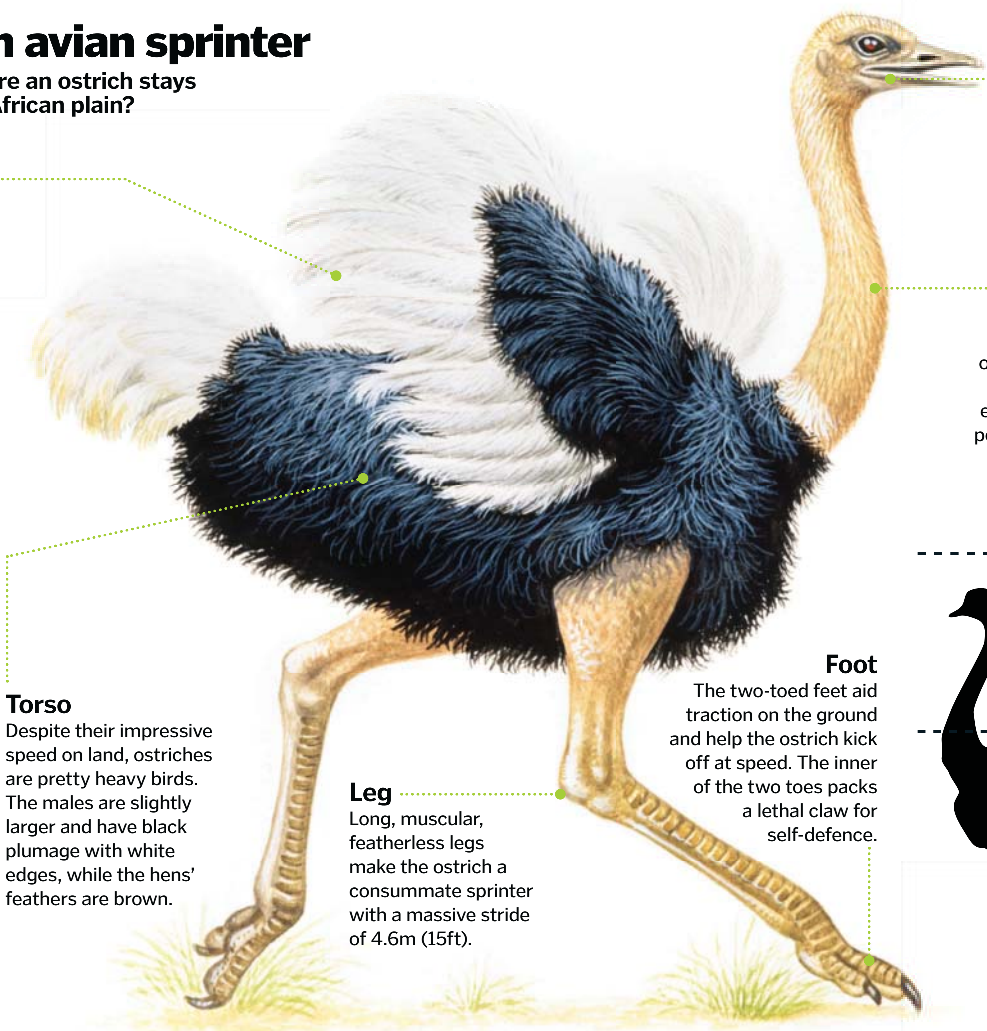
An ostrich's long, powerful legs are also bare, ensuring they remain as streamlined as possible – much like athletes who shave their legs or wear tight clothing.

Burying the myth for good

While being tall and leggy might enable an ostrich to outrun most predators, it also makes it hard to be inconspicuous. Almost half of an ostrich's total height is made up by its neck and so that's the most obvious body part to hide from view. However, while a young ostrich will often lie down with its neck flat on the ground to avoid detection, the birds also get down on the floor to rearrange their eggs that are buried in the dust. The idea that they foolishly bury their heads in the sand at the first sign of imminent danger, however, is actually a complete myth.

Anatomy of an avian sprinter

What characteristics ensure an ostrich stays ahead of the pack on the African plain?



Head
The ostrich has the largest eyeballs of any of today's birds, and its small head is also covered in downy feathers.

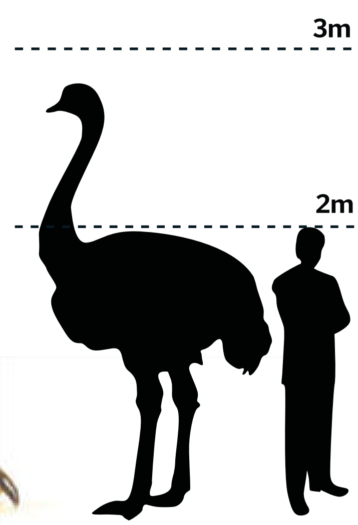
Wing
Though their wings are very weak, they are still quite large for a bird of this size – indeed, the wings can span up to 2m (6.5ft). They aren't totally useless as when outstretched they make for great rudders for steering.

Neck
The neck accounts for nearly half of an ostrich's great height, which makes it well equipped for spotting potential danger early.

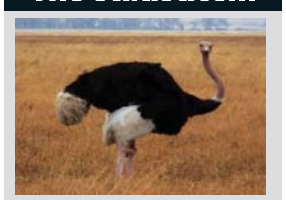
Torso
Despite their impressive speed on land, ostriches are pretty heavy birds. The males are slightly larger and have black plumage with white edges, while the hens' feathers are brown.

Leg
Long, muscular, featherless legs make the ostrich a consummate sprinter with a massive stride of 4.6m (15ft).

Foot
The two-toed feet aid traction on the ground and help the ostrich kick off at speed. The inner of the two toes packs a lethal claw for self-defence.



The statistics...



Ostrich

Binomial: Struthio camelus
Type: Bird
Diet: Omnivore (though primarily a herbivore, they are known to eat carrion and insects too)
Average life span in the wild: Up to 40 years
Weight: 90-150kg (200-330lb)
Height: 2.75m (9ft)
Top speed: 72.5km/h (45mph)
Habitat: Dry and sandy regions of Sub-Saharan Africa

"Four decades later the gas continues to blaze, lighting up the surrounding region for miles"

Who opened the Door to Hell?

How It Works explores a gas crater in Turkmenistan which has been burning nonstop since 1971

The Derweze natural gas crater is a basin 70 metres (230 feet) across located in the middle of the Karakum Desert in Turkmenistan. The crater, which was created when a natural gas drilling rig and camp collapsed in 1971, is informally referred to by the local people as the 'Door to Hell', as for the past 42 years it has been on fire.

The flames were instigated when a Soviet Union drilling team decided that, after their rig collapsed, the best way to deal with the large amount of methane gas spilling out into the environment was to burn it off. Geologists at the time predicted that the methane would combust within days, but four decades later the natural gas continues to blaze, lighting up the surrounding region for miles.

Today, the Door to Hell is something of a tourist attraction, with travellers flocking to the nearby village of Derweze – which has a population of only around 350 people – from all over the world. Typically tour groups venture to the site in the evening, as the crater's fiery glow is more dramatic in the low light of dusk than during the day, as shown here.

DID YOU KNOW? The Derweze natural gas field is 260km (162mi) north of Ashgabat, Turkmenistan's capital city

© Tormod Sandtorv

RECORD BREAKERS
R-EEL-LY DEEP

8,370m

DEEPEST RECORDED FISH

A basketweave cusk-eel was discovered at a depth of 8,370 metres (27,460 feet) – that's 8.4 kilometres (5.2 miles) down – in the abyssal zone of the Puerto Rico Trench, making it officially the deepest living fish known.

DID YOU KNOW? *Moray eel jaws are strong enough to bite off a human finger!*

How moray eels feed

Find out why catching a fish dinner is a doddle when you've got two mouths

The moray eel is a slender, reef-dwelling fish native to the nooks and crannies of subtropical and temperate seas. While they are voracious eaters, they are not great swimmers due to their lack of a pectoral fin. Instead they lurk almost motionless in rocky crevices, often with just their heads peeking out, waiting for a meal to swim by.

Most other bony fish have developed a method of slurping up prey by very rapidly opening their mouths to create an area of negative pressure directly in front of them. This quickly draws water – and any unsuspecting victim – back into the mouth cavity. While fish that bite also use suction to get food from their mouths into their throats, the moray eel doesn't. In fact, few fish consume their food in as impressive – or terrifying – a manner as the moray eel.

Because they live in tight crevices, the suction method wouldn't work for a moray because the head has no space to expand into. And besides, the eel's prey is generally too large to really be affected by the suction technique. Instead, morays are the only known species of vertebrate to possess two pairs of jaws. It sounds like some kind of special-effects monster from the *Alien* movies, but the moray eel has a second set of raptorial jaws in its pharynx: the pharyngeal jaws. These gnashers located behind the eel's skull lurch forward after the fish has taken the initial bite and grab at the victim, drawing it back down into the throat so the eel can swallow it.

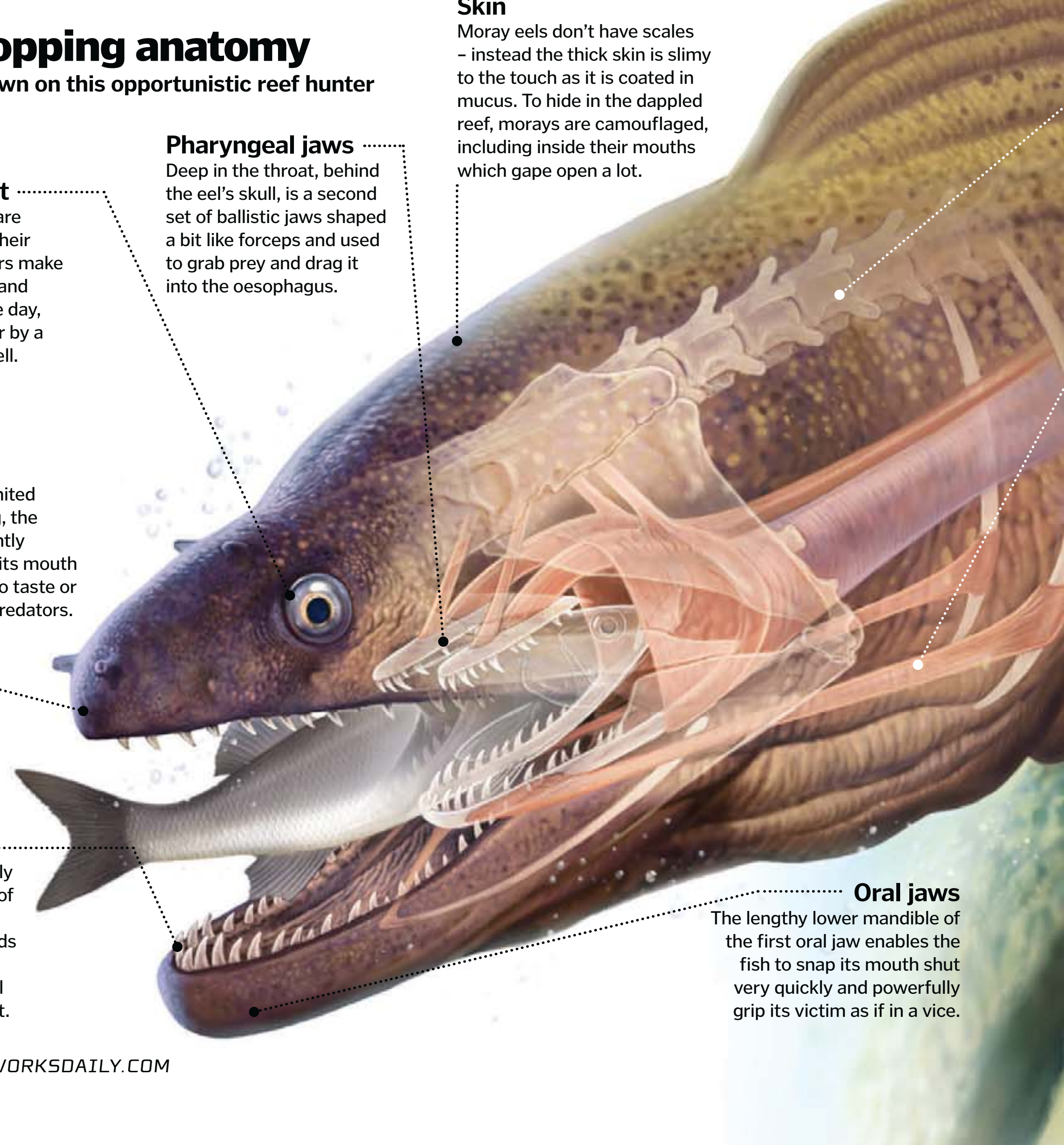
It's thought that these movable second jaws are a result of adaptation to suit the confined spaces these fish tend to inhabit in reef environments.

Off the menu

Moray eels are high up the food chain, which leaves them more susceptible to the accumulation of toxins. Ciguatoxin, for instance, is a nasty organic compound made by a specific type of dinoflagellate (a single-celled organism). At first the ciguatoxin may be consumed by a snail, which may then be eaten by a crab; the crab might become dinner for a larger fish and so on until, finally, the moray eel eats something contaminated. Essentially, the higher up the food chain, the greater the toxin concentration. Cooking does not destroy ciguatoxin so it's safest simply to avoid eating moray eels.

Jaw-dropping anatomy

Get the lowdown on this opportunistic reef hunter



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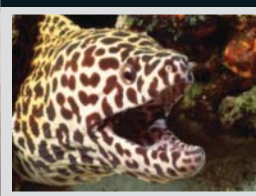


Moray eel

Binomial: Muraena retifera
Type: Fish
Diet: Carnivore, eg fish, crustaceans and cephalopods
Average life span in the wild: 10-20 years
Weight: Up to 30kg (66lb)
Length: Up to 3m (9.8ft)
Habitat: Generally bottom dwellers worldwide (tropical and temperate oceans)

"The Amazon absorbs nearly 2 billion tons of carbon each year, making it essential to life on Earth"

Deforestation spells disaster for global biodiversity as many species' natural habitat shrinks at an alarming rate

Deforestation explained

What are the environmental consequences of clearing acres of rainforest in the Amazon?

Deforestation is when a wooded area like part of a rainforest is cleared to make way for a different type of land use – usually for human activities such as livestock grazing, crop farming and commercial logging. Such environmental destruction has been going on throughout history; in the 19th century, for example, much of the eastern area of North America was cleared for colonisation and agriculture. When we think of deforestation today, however, the world's tropical rainforests immediately spring to mind. As well as remarkable biodiversity rainforests are important because they preserve the delicate balance of life on Earth.

Everybody knows that trees capture energy from the Sun to make their own food – a process called photosynthesis – and a by-product of this is the release of oxygen into the atmosphere for us to breathe. The Amazon actually produces 20 per cent of Earth's oxygen. Such forests are also referred to as carbon sinks as they soak up around 18 per cent of the carbon dioxide that enters the atmosphere from burning fossil fuels. The Amazon rainforest absorbs nearly 2 billion tons of carbon each year, making this forest essential to continued and successful life on our planet. Logging and burning releases carbon sequestered by the trees and other plants back into the atmosphere as carbon dioxide. In fact, the action of deforestation now contributes about 20 per cent of all greenhouse gas emissions – that's more than all planes, trains and automobiles put together! By absorbing carbon dioxide from the atmosphere, rainforests also in turn perform a significant role as climate moderators, and in the long term – if mass deforestation continues – it will have a profound effect on not just day-to-day weather but also seasonal climate worldwide.

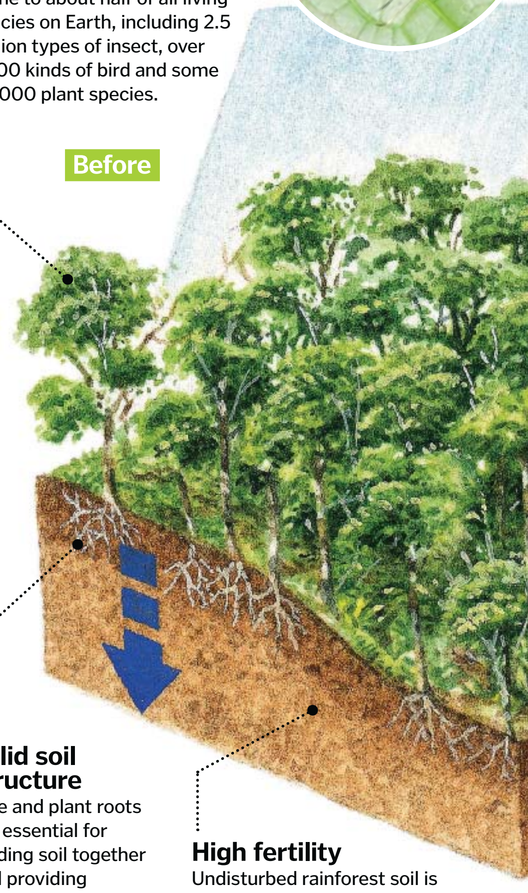
As land is cleared, roads are often built illegally which enable tractors and bulldozers to venture deeper into the heart of the rainforest, facilitating the spread of deforestation. As machines move in to fell thousands of trees every day, the forests' inhabitants – like jaguars, golden lion tamarins and toucans to name just three – are fast running out of places to hide. The clearing of trees doesn't only mean the loss of precious habitats – it's often a prelude to the imminent extinction of entire species.

Deforestation before and after

How is the chopping down of millions of trees impacting the Amazon rainforest?

Biodiversity

Rainforests are characterised by high rainfall, high temperatures and year-round sunshine, making them abundant with more exotic species than anywhere else on Earth. The Amazon rainforest is home to about half of all living species on Earth, including 2.5 million types of insect, over 1,000 kinds of bird and some 60,000 plant species.



Solid soil structure

Tree and plant roots are essential for binding soil together and providing stability for the land.

High fertility

Undisturbed rainforest soil is rich with decaying leaf litter providing a kind of constant compost, meaning flora grows quickly and species are very varied. Plants that like shade on the forest floor particularly suffer when trees are cut down.

The impact of palm oil

A huge cause for concern is the ever-rising demand for palm oil. Many areas of Africa and south-east Asia are being cleared to make way for palm oil plantations. This product, extracted from the fruit of the oil palm tree, is extremely useful to a variety of industries, including the processed-food industry due to its versatility and low price. It's also used widely in the cosmetics world as a cheap alternative to expensive natural oils used in soaps and moisturisers and it even has uses natively as a fuel for heating, cooking and lighting.

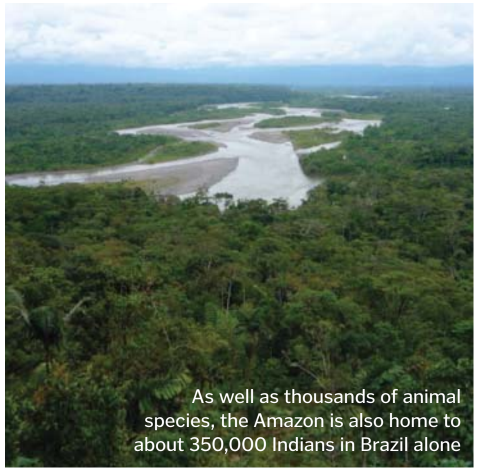
THE STATS
FOREST FIGURES

EARTH'S SPECIES IN RAINFORESTS	50%
TREES FELLED PER MINUTE	2,000
CATTLE IN BRAZIL	220mn
SPECIES LOST ANNUALLY	50,000
ORIGINAL FORESTS STILL INTACT	22%
FORESTED AREA LOST PER YEAR	1%

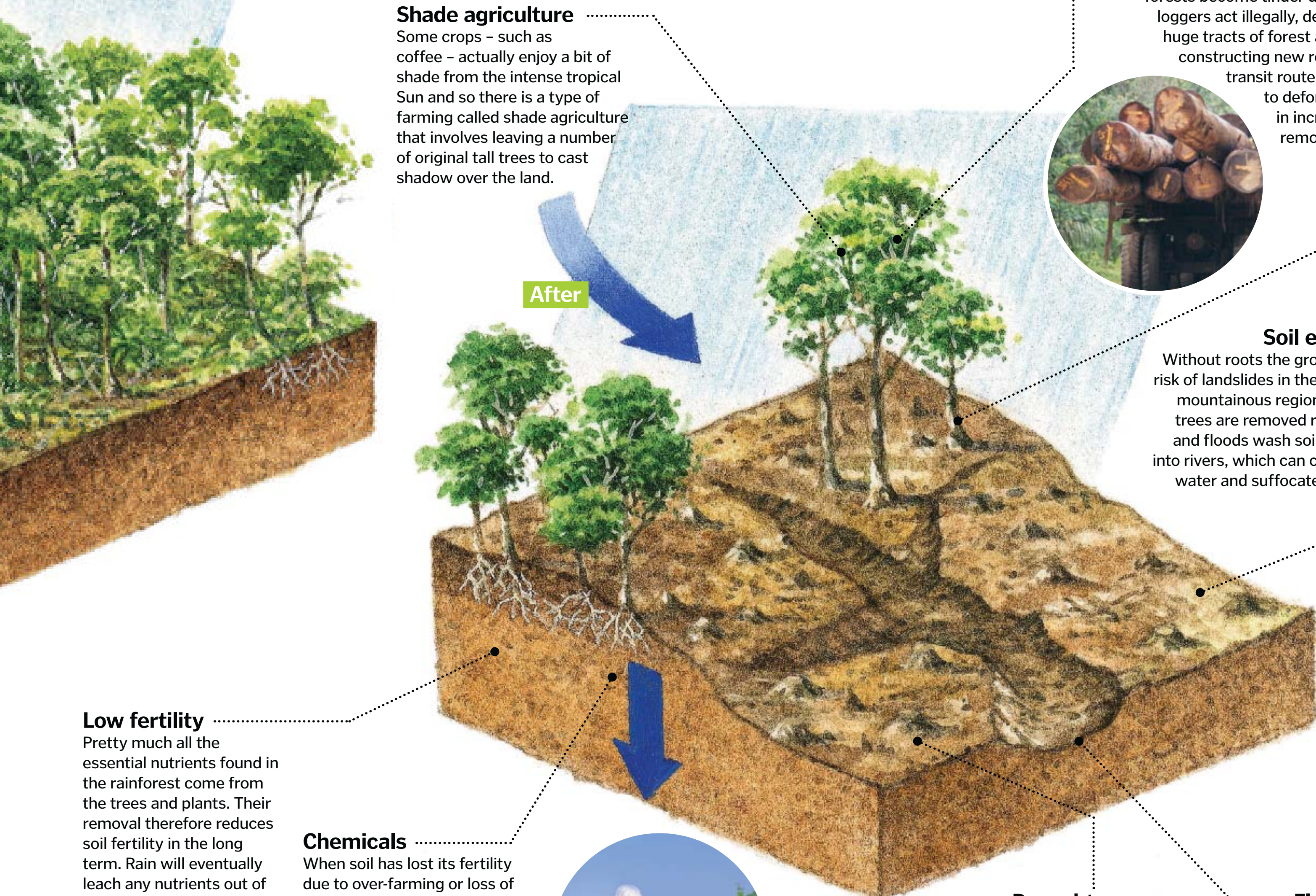
DID YOU KNOW? *Lyrebirds mimic sounds they hear and, poignantly, one was recorded mimicking a chainsaw*

Spotlight on the Amazon

The forests of South America have been particularly ravaged by deforestation. In the Eighties it was discovered that vast tracts of the Brazilian Amazon rainforest were being cleared for such human activities as cattle ranching (70 per cent), commercial agriculture (25 per cent) and logging (five per cent). Indeed, until 2011 Brazil was the world's largest exporter of beef. The land was very flat and therefore easy to farm which was an attractive proposition for big businesses. While wildlife habitats were replaced by cattle ranches, the intensive destruction of exotic plant life also made way for mass-produced crops such as soy. Huge soybean plantations yielded this cheap protein substitute as a valuable export commodity. It was also discovered that some of the biggest multinational companies, supermarkets and fast-food chains in the world had been sourcing soy from the illegal destruction of the Amazon. This exposé on deforestation saw many corporations re-evaluate their practices and suppliers, moving to use only sustainable sources of soy.


As well as thousands of animal species, the Amazon is also home to about 350,000 Indians in Brazil alone

Slash and burn
Though often carried out by small-scale farmers, this method of cultivation can have a devastating impact on the forest. It involves the felling and burning of trees to create a space for farming or cattle rearing. The burned trees produce a rich ash, which is scattered over the land to temporarily fertilise the ground. This technique releases lots of CO_2.



Shade agriculture
Some crops – such as coffee – actually enjoy a bit of shade from the intense tropical Sun and so there is a type of farming called shade agriculture that involves leaving a number of original tall trees to cast shadow over the land.

Logging
Logging makes rainforests more prone to wildfires as humid forests become tinder dry. Many loggers act illegally, destroying huge tracts of forest and even constructing new roads and transit routes leading to deforestation in increasingly remote areas.

Soil erosion
Without roots the ground is at risk of landslides in the steeper, mountainous regions. When trees are removed rainwater and floods wash soil straight into rivers, which can choke the water and suffocate wildlife.

Low fertility
Pretty much all the essential nutrients found in the rainforest come from the trees and plants. Their removal therefore reduces soil fertility in the long term. Rain will eventually leach any nutrients out of the soil, leaving the area as good as useless for farming after just two or three years. If abandoned, it can then take up to 50 years for cleared rainforest to grow back again due to the low-nutrient earth.

Chemicals
When soil has lost its fertility due to over-farming or loss of plant nutrients it is no good for plantation. Farmers will often introduce strong pesticides and fertilisers to ensure the soil is up to sustaining more crops year after year. In turn this kills off many organisms, further contributing to poor soil quality.

Drought
The Amazon has been experiencing increasingly severe droughts due to deforestation. As well as anchoring soil in place, trees also allow water to infiltrate the ground, keeping aquifers (underground water stores) topped up.

Flooding
With no trees to absorb water, flash flooding is common after deforestation. Drainage networks built by developers have also contributed to the increase of surface run-off into rivers and streams.

Space telescopes

Why do space agencies launch telescopes off Earth and how do they capture so much detail?

THE STATS
SPACE SCOPES

JWST GOLD COATING	48.25g	FERMI'S ORBIT	95 mins	HERSCHEL'S LIQUID HELIUM COOLANT	2,271 litres
JWST PAYLOAD	6,200kg	SPITZER DISTANCE FROM EARTH	176mn km	HUBBLE DUE TO DEORBIT	2020

DID YOU KNOW? *IR space telescopes like Herschel need to be cooled to below -270°C (-454°F) by liquid helium*

Computer artwork of the Hubble Space Telescope (HST) in orbit over Earth. The HST is a collaboration between NASA and the European Space Agency (ESA), orbiting at a height of around 600km (370mi)

Great Observatories under the microscope

Over 13 years from 1990 to 2003, NASA launched a series of four orbital telescopes that have collectively come to be known as the Great Observatories. Their origins lie back in the late-Seventies and early-Eighties when it was decided that the planned Hubble Space Telescope programme would benefit from three other telescopes, each covering different areas of the electromagnetic spectrum. Shortly after the launch of Hubble in 1990 with its eye on the visible and near-ultraviolet wavelengths, was the Compton Gamma Ray Observatory (1991). The Chandra X-ray Observatory launched third and the Spitzer Space Telescope was the final one in 2003, detecting the long wavelengths of the infrared spectrum. Only Hubble and Chandra are still in a terrestrial orbit, with Spitzer trailing the Earth in a solar orbit and Compton having been deorbited in 2000 after a gyroscope failed.

Hubble's top discoveries

Some of the biggest revelations in modern astronomy are a direct result of observations using the Hubble Space Telescope (HST). This includes a more accurate approximation of the age of the universe: by measuring the brightness of Cepheid variable stars, which are a reliable marker for astronomical distances, scientists were able to narrow the age of the cosmos from between 10 and 20 billion years to 13.75 billion years. Hubble was also able to pick out distant supernovas invisible from Earth, giving astronomers a much better idea of the role dark energy played in the early cosmos.

More recently, since Hubble's 2009 upgrade of the Wide Field Camera 3, the HST has been able to take multiple images of galaxies over 13 billion light years away, effectively taking snapshots of the universe in its infancy, when it would have been a 'mere' 600 million years old.

The German astrophysicist Hermann Oberth had a number of ideas that were considered radical for his time. Indeed, during the Twenties, he wrote several papers on space exploration, sending manned rockets into space and he also talked about putting a giant telescope into orbit around the Earth. Fortunately for Oberth, he got to see these theories become reality in the Space Race that played out in the mid-20th century.

The first of the four Orbiting Astronomical Observatory satellites, OAO-1, was launched in April 1966 but was terminated after a power failure rendered its instruments useless. The second, OAO-2, was launched in December 1968 and successfully deployed its 11 ultraviolet telescopes to become the first device to observe space from orbit. The next model, Space OAO-B, also failed, but the final OAO-3 space telescope – which was dubbed Copernicus – was the most successful in this series and included an X-ray detector, paving the way for more powerful space telescopes capable of observation in many different wavelengths.

In the wake of the hit-and-miss Orbiting Astronomical Observatories, a flurry of space telescopes has been sent up to circle our planet and, more recently, the L2 Sun-Earth Lagrange point. We've even managed to put one – the Spitzer Space Telescope (SST) – into solar orbit.

Some of these, like the world-famous Hubble, have been invaluable in our pursuit of astronomical knowledge. But sending anything into space is expensive: Hubble alone cost £1.6 billion ($2.5 billion) to construct and, including the five shuttle missions required for maintenance and repair, a further £4.8 billion ($7.5 billion) to keep it operational. Compare that to the £830 million ($1.3 billion) it cost to build the Atacama Large Millimeter/submillimeter Array (or ALMA) – the planet's most expensive terrestrial telescope – and you may be left wondering why we bother with the off-Earth variety. There's a very good reason though.

In the case of Spitzer, it can take far more detailed images of celestial objects from the proximity of its solar orbit. However one of the main reasons why we send telescopes into space is to get out of Earth's atmosphere, which selectively scatters visible light and blocks many different wavelengths of the electromagnetic spectrum, restricting our view of space. By blocking some of the ultraviolet part of the electromagnetic spectrum, X-rays and other high-energy radiation that is harmful and even deadly to most organisms, our atmosphere has enabled life to flourish on Earth. But those frequencies carry a mine of information about the cosmos and can provide images that simply can't be captured from a terrestrial vantage point.

Since the Sixties space telescopes have become increasingly sophisticated. Among the dozens that we've sent into orbit – including Fermi, Planck and the three remaining space telescopes of the Great Observatories programme (see boxout for more detail) – the upcoming launch of the James Webb Space Telescope (JWST; named after a NASA administrator) will allow us to see farther than ever and hopefully learn even more about our universe.

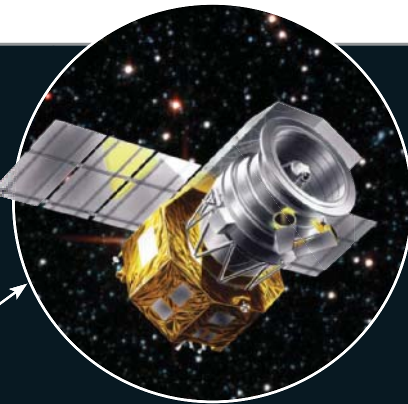
"Herschel can see the coldest objects in space, spotting the ingredients for life among the stars"

Charting the cosmos

Meet some of the world's most important space telescopes and find out what they're looking for

Planck
14 May 2009 – present
Launched alongside the Herschel, the ESA's Planck observes cosmic microwave background radiation and reveals the history of the universe.

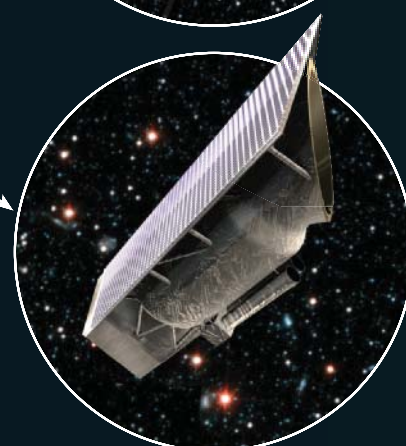
AKARI
21 February 2006 – 24 November 2011
This Japanese satellite was designed to make a complete survey of the sky. It managed this successfully – twice – before a major power failure in 2011.



JWST
2018 (scheduled launch)
The James Webb Space Telescope has four main objectives that include studying planetary systems and seeking out the origins of life.

Herschel Space Observatory
14 May 2009 – present
Herschel can see the coldest objects in space, spotting the ingredients for life among the stars. It is the largest infrared telescope launched yet.

ISO
17 November 1995 – 16 May 1998
Avoiding local heat sources (like the Sun and the other planets in the Solar System), the Infrared Space Observatory was able to detect the birth and death of distant stars.



Across the spectrum

What role does electromagnetism play in space observation and how do the radiations differ?

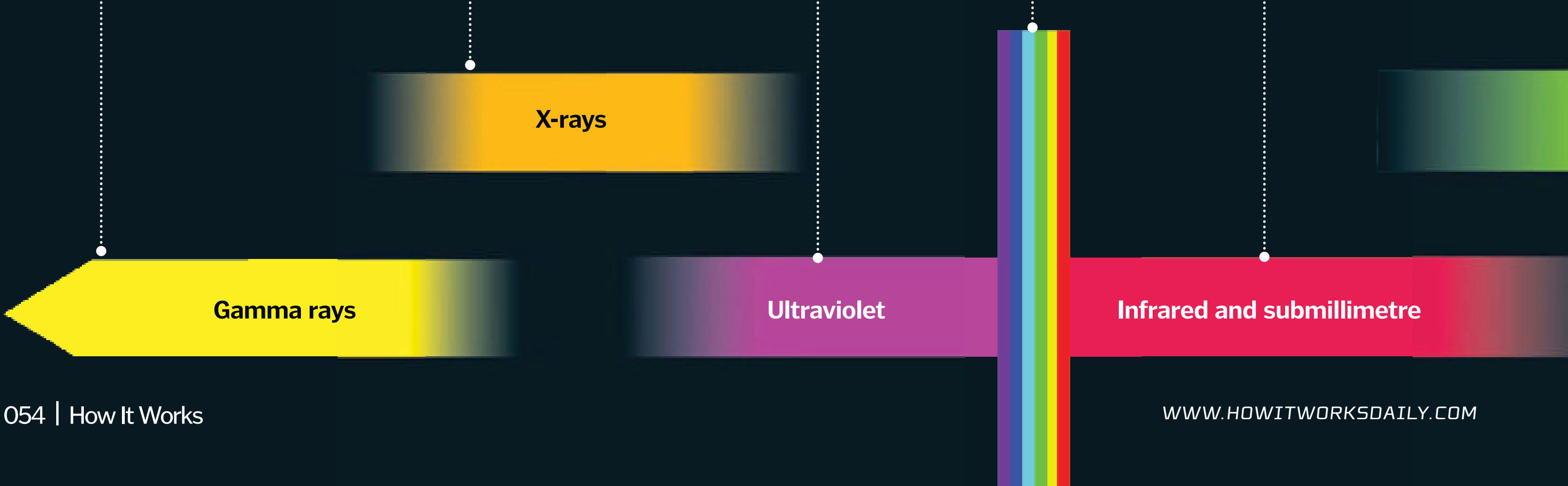
Gamma rays
Gamma rays are emitted by very violent events and high-energy sources in the universe, such as supernovas, neutron stars and gamma-ray bursts. They're absorbed by our atmosphere, so are invisible from Earth's surface.

X-rays
Like gamma rays and other high-energy, short-wavelength emissions, X-rays are also restricted by our atmosphere but can travel a short way through the upper levels. X-rays are typically emitted by black holes and some stars.

Ultraviolet
UV is mostly filtered out by our atmosphere and telescopes need to be launched into the upper atmosphere or beyond to effectively observe it. Space telescopes capture excellent images of the Sun in UV.

Visible light
This part of the EM spectrum is allowed through the atmosphere, or we wouldn't be able to see! To avoid distortion by atmospheric effects, visible-wavelength telescopes are put into space.

Infrared and submillimetre
Colder astrophysical objects like brown dwarfs and nebulas emit lower-energy light in these wavelengths. This is typically the wavelength that redshifting galaxies are observed in.



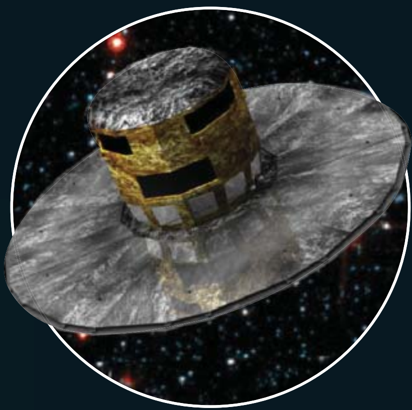
AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

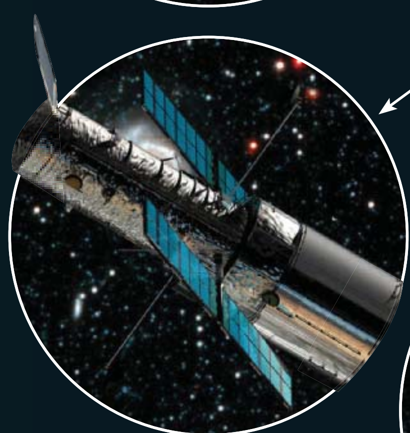
See a Hubble galaxy created in two minutes!

www.howitworksdaily.com

DID YOU KNOW? The JWST was named after the NASA administrator who managed the Apollo programme



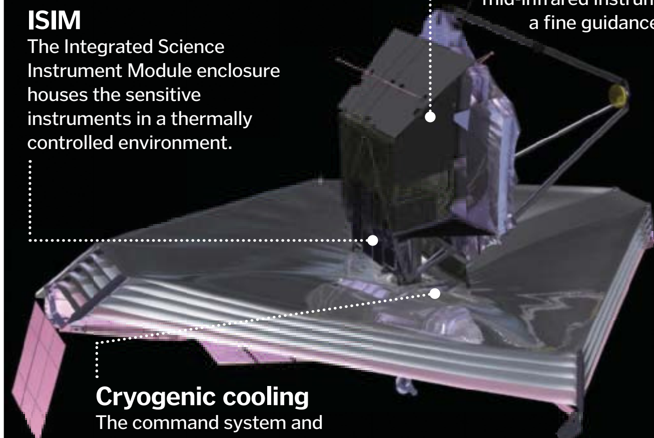
Gaia
October 2013 (scheduled launch)
The Global Astrometric Interferometer for Astrophysics aims to create a 3D space image of 1 billion stars.



Hubble Space Telescope
24 April 1990 – present
The longest-serving space telescope has snapped some incredible visible and near-UV images of the edge of the universe.

JWST in brief

What will be on board this space telescope due to launch in 2018?



ISIM
The Integrated Science Instrument Module enclosure houses the sensitive instruments in a thermally controlled environment.

Instrumentation
Instruments include an infrared camera, a near-infrared spectrograph, a mid-infrared instrument and a fine guidance sensor.

Cryogenic cooling
The command system and cryogenic compressor will keep detectors cooled to 39 Kelvin.

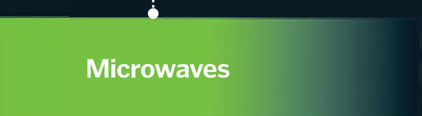
International Ultraviolet Explorer
26 January 1978 – 30 September 1996
The collaborative IUE space telescope was the most successful of its time, making unprecedented observations of quasars and black holes. It operated for over 18 years.

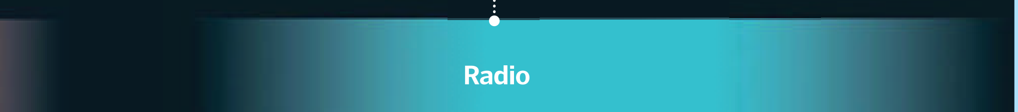
International Gamma-Ray Astrophysics Laboratory
17 October 2002 – present
Scanning the sky for the highest-energy emissions in space, Integral is the world's most sensitive gamma-ray observatory designed to spot gamma-ray bursts (GRBs) etc.

XMM-Newton
10 December 1999 – present
The X-ray Multi-Mirror telescope operates in X-ray frequencies, mapping dark matter and black holes as well as investigating any objects spotted by Hubble.

Microwaves
There's plenty of this low-energy form of radiation around, but a lot of it needs to be gathered to create a viable image. The cosmic microwave background left over from the Big Bang is studied in this wavelength.

Radio
Earth's atmosphere is completely transparent to radio waves, so most radio space telescopes are used to verify powerful ground radio telescopes such as ALMA. Gravitational lensing and supernova remnants can be observed at this frequency.





Seeing infrared

The incredible telescope images space agencies put out aren't exactly what you'd see if you were floating in Earth orbit, peering through a telescope. Don't feel cheated though as they are accurate. In the case of infrared, ultraviolet or other wavelengths invisible to the human eye, false-colour imaging is necessary to make the pictures visible. Three or four raw images from various wavelengths are taken to be layered; in the case of visible light, images are taken in red, green and blue filters. They're stacked like slides in a photo-editing suite where the light levels are tweaked and any artefacts can be erased.

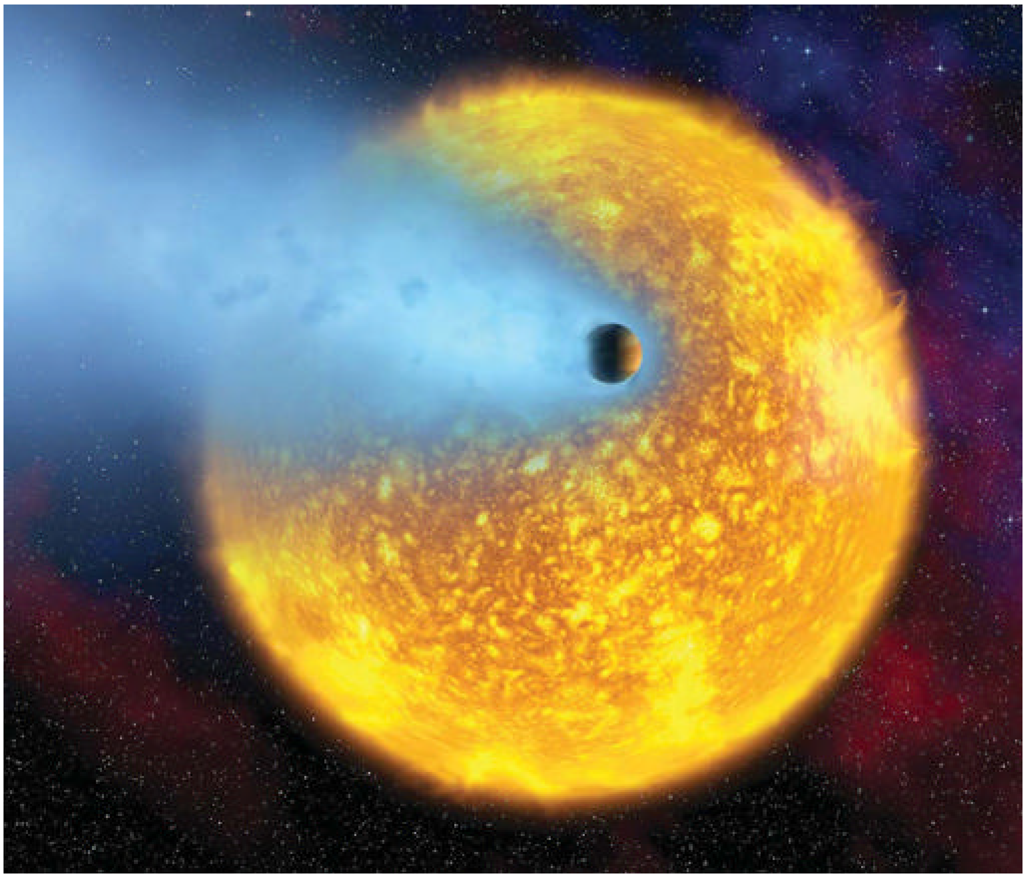
THE STATS
OSIRIS IN NUMBERS

ORBITAL PERIOD	3.5 days	DISTANCE TO SUN (KM)	780mn	DATE OF DISCOVERY	5/11/1999
ORBITAL RADIUS FROM STAR (KM)	7mn	SURFACE GRAVITY	1.88 g	ESTIMATED LIFETIME	5bn years

DID YOU KNOW? *Superstorms have been seen tearing across Osiris with wind speeds of up to 10,000km/h (6,215mph)*

How do planets evaporate?

Why is the gas giant Osiris dissolving into space?



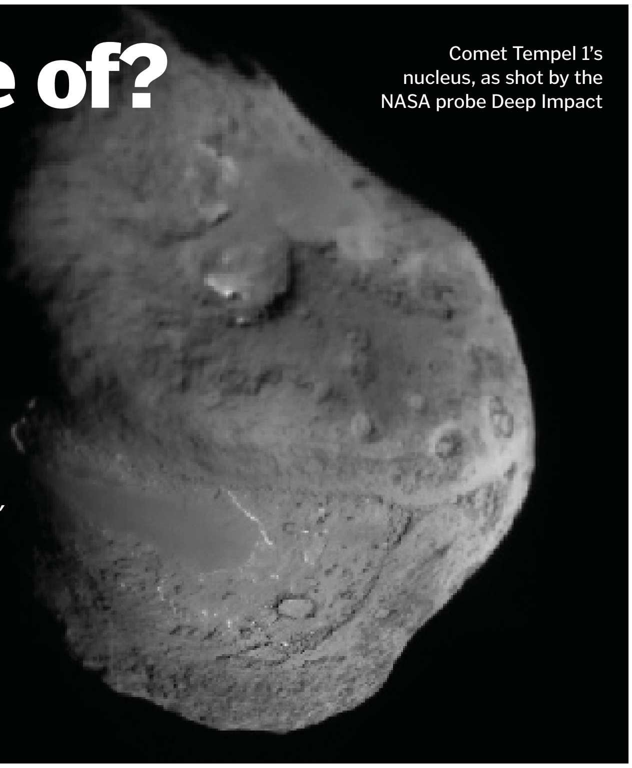
Osiris (officially designated HD 209458b) is a large planet around two and a half times the size of Jupiter and 220 Earth masses, orbiting a yellow dwarf star 150 light years from Earth. It's one of the first extrasolar planets discovered that has an atmosphere with hydrogen, carbon and oxygen – an indication that it has water vapour too. It might seem like a good place to look for a habitable environment, but for one thing: Osiris's atmosphere is evaporating.

The planet orbits its parent star at a radius of one-eighth that of Mercury's, resulting in a blistering hot surface temperature of around 1,000 degrees Celsius (1,832 degrees Fahrenheit). As a result, its atmosphere is boiling away, potentially at a rate of 10,000 tons per second, leaving a massive tail 200,000 kilometres (125,000 miles) long in its wake.

Evidence of water vapour is based on observations that were first made by the Hubble Space Telescope in 2007, and in 2009 it became the first planet outside the Solar System to show hard proof of the life-sustaining liquid.

What's a comet made of?

How It Works examines the major minerals and chemicals that make up your average comet



Comet Tempel 1's nucleus, as shot by the NASA probe Deep Impact

Comets pass near enough to Earth to feature regularly in our skies. The famous Halley's Comet, for example, passes us roughly every 75 years and is next expected to be visible from our planet in 2061.

Comets are generally known to be made of ice and frozen dust but, in the pursuit of discovering exactly what the composition of a comet was, NASA decided to analyse a chunk of one. This was no mean feat and a dedicated mission called Deep Impact was set up to send a probe into space to investigate the cosmic projectile. The probe shot a small impactor into the core of Jupiter family comet Tempel 1, which threw up debris that allowed both the probe and various telescopes to study its makeup using infrared spectrometry.

By breaking apart the light reflected from this debris, the Spitzer Space Telescope was able to determine the chemical signatures of a huge variety of compounds. This included forms of iron, clays, carbonates, silicates and – perhaps most curiously – the mineral which makes up the gemstone spinel (one of which appears in the British Crown Jewels). The vapour trail was determined to be comprised of water vapour and carbon dioxide gas.

5 TOP FACTS
EUROPA TRIVIA

Discovery
1 The astronomer Galileo Galilei first discovered Europa in 1610 along with Ganymede, Callisto and Io, Jupiter's largest moons. They're now known as the Galilean moons in his honour.

Orbital period
2 Ganymede, Europa and Io have orbital periods that are closely related: Io will orbit Jupiter twice for every one of Europa's orbits and four times for every one of Ganymede's.

Project Prometheus
3 As a part of the now cancelled fission engine spacecraft programme, a small nuclear-powered craft was proposed for landing on Europa to act as a communication relay.

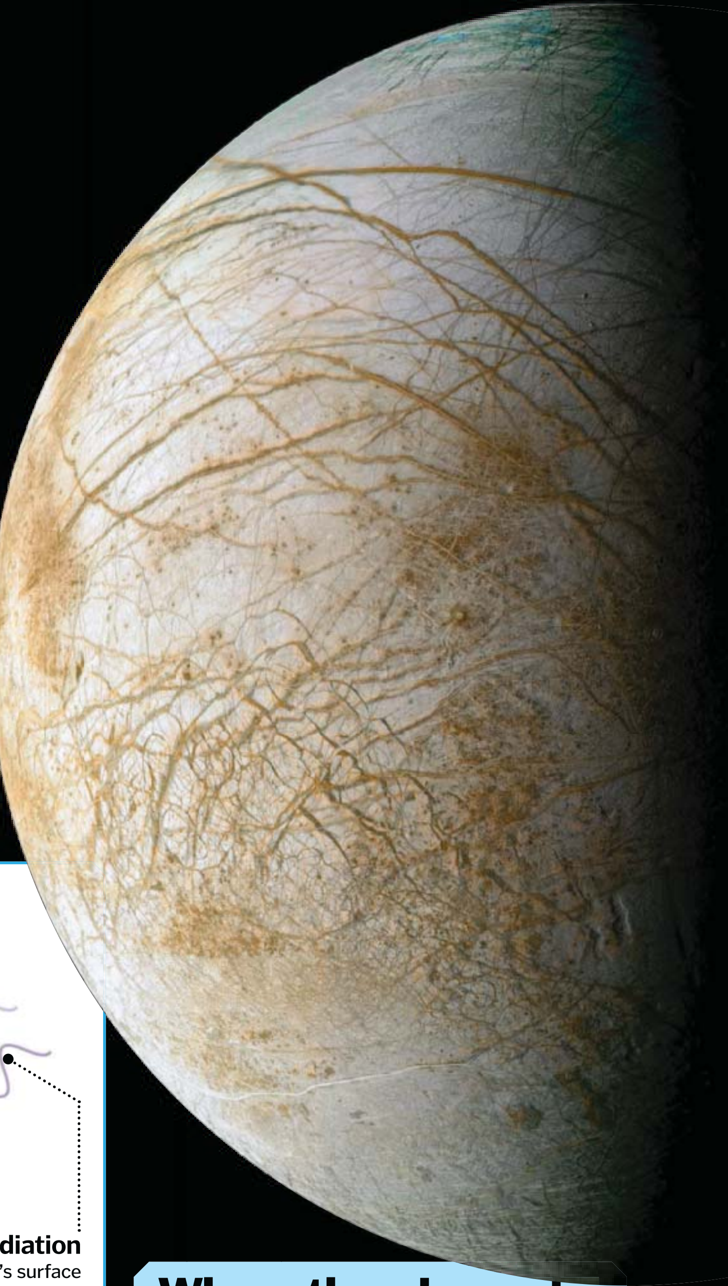
The big melt
4 One of the more ambitious proposals to explore Europa was to land a craft that would melt through the ice until it reached the ocean below, then send out a probe.

Artemis Project
5 A private venture that also planned to colonise the Moon in 2002 proposed to drill into Europa's crust and create a base in a pocket between the ice and the subsurface ocean.

DID YOU KNOW? *In the 1982 Arthur C Clarke novel 2010: Odyssey Two, Europa is the hallowed moon that shows signs of life*

Inside Europa

Can this icy satellite orbiting Jupiter really hold the essential ingredients for life?

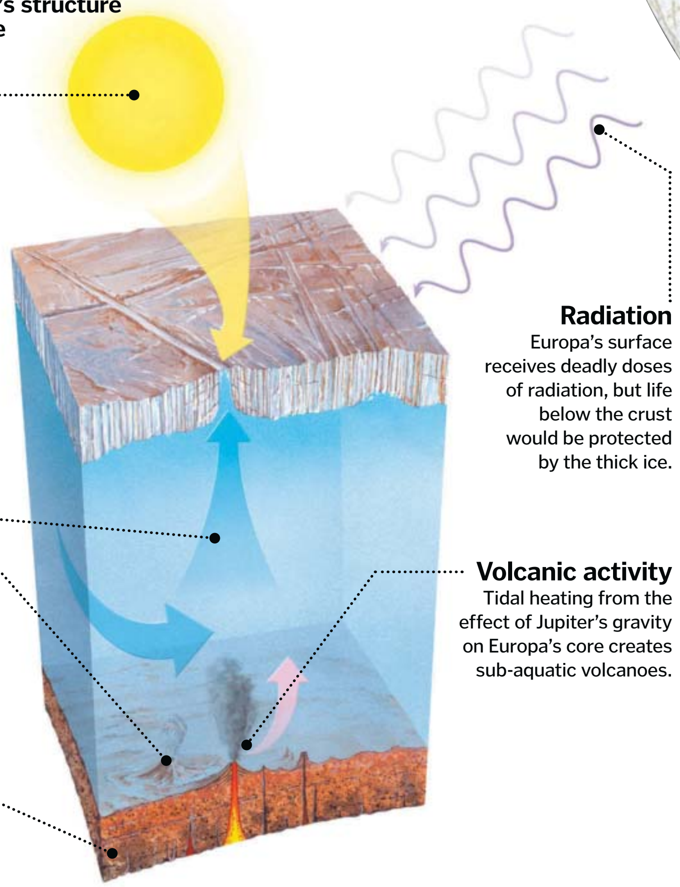


In recent years scientists have come to regard the smallest of the four Galilean satellites, the moon Europa, as a potentially habitable world and even the most likely possible host for extraterrestrial life in the Solar System. But how could that be? The moon orbits Jupiter at over five astronomical units, or nearly 800 million kilometres (500 million miles) from the Sun, has a surface pressure around 100 billion times weaker than Earth's and even its hottest summers only reach -160 or so degrees Celsius (-256 degrees Fahrenheit). Indeed, it's so cold that its surface is an icy crust measuring 150 kilometres (90 miles) thick at its deepest.

However, that ice is frozen water – one of the vital precursors for life and below the ice it's believed there may be a layer of liquid water. This is suggested by the relative flatness of the surface, and pictures taken by the Galileo probe as it orbited Jupiter indicated the crust was warmer and more mobile at one point in its history. Scientists also believe tidal heating via the immense pull of Jupiter's gravity on Europa, as it moves through an elliptical orbit around the gas giant, could be what is keeping the subsurface layer melted. If we can confirm the presence of liquid H_2O and an energy source from tidal heating, then ET life on Europa is certainly a viable prospect.

Beneath the surface...

Learn how this Jovian moon's structure might be able to harbour life



Sunlight
At Europa's distance from the Sun, sunlight is too weak to be an energy source for life.

Tidal circulation
Continuous circulation and heat from volcanic activity would keep the subsurface water in a liquid state.

Geothermal vents
In the deep interior of Europa, life can derive energy from geothermal vents and thrive in the warmer water.

Rocky bed
The magnetic iron core of Europa is surrounded by a crust of rock.

Radiation
Europa's surface receives deadly doses of radiation, but life below the crust would be protected by the thick ice.

Volcanic activity
Tidal heating from the effect of Jupiter's gravity on Europa's core creates sub-aquatic volcanoes.

Where there's smoke

One of the reasons why scientists think that life is still possible in such chilly, dark conditions is because of an expedition that changed our concept of life. It wasn't to a distant planet either, but to one of the deepest oceanic rifts found on Earth. In the late-Seventies, the deep-sea submersible Alvin was searching a trench in the Galápagos Rift when it came across something completely unexpected: clams, crustaceans and other organisms. Previously it was thought all life derived its energy from the Sun and it was possible to live in the pitch black of the deep only by feeding on the rain of detritus from the surface. However, this was a completely independent food chain that derived its energy from a hydrothermal vent driven by geothermal energy, known as a black smoker, which belched out a soup of chemicals. The bacteria that live off these compounds could be a possible model for life on Europa too.

"The image is captured in infrared and made up of 300,000 individual tiles"

Inside the Large Magellanic Cloud

What is this sprawling celestial feature and how was this stunning image captured?

The Large Magellanic Cloud (LMC) isn't a cloud at all – it's actually one of several dwarf galaxies that orbit a short distance from the Milky Way. When we say a 'short' distance, we mean astronomically short: it's roughly 160,000 light years from Earth and it's not that 'dwarf' either. At 14,000 light years in diameter, it comes to about one per cent the mass of our own galaxy.

As you might expect, all that makes the LMC a fairly easy celestial subject to spot in the cosmos. But to create this image – the sharpest and most accurate shot of this galaxy to date – NASA's orbiting Spitzer Space Telescope had to go to great lengths. It's captured in infrared and made up of 300,000 individual tiles, using a process that was 1,000 times more sensitive than techniques used in previous missions, which accounts for the super-high degree of detail seen in the final image.

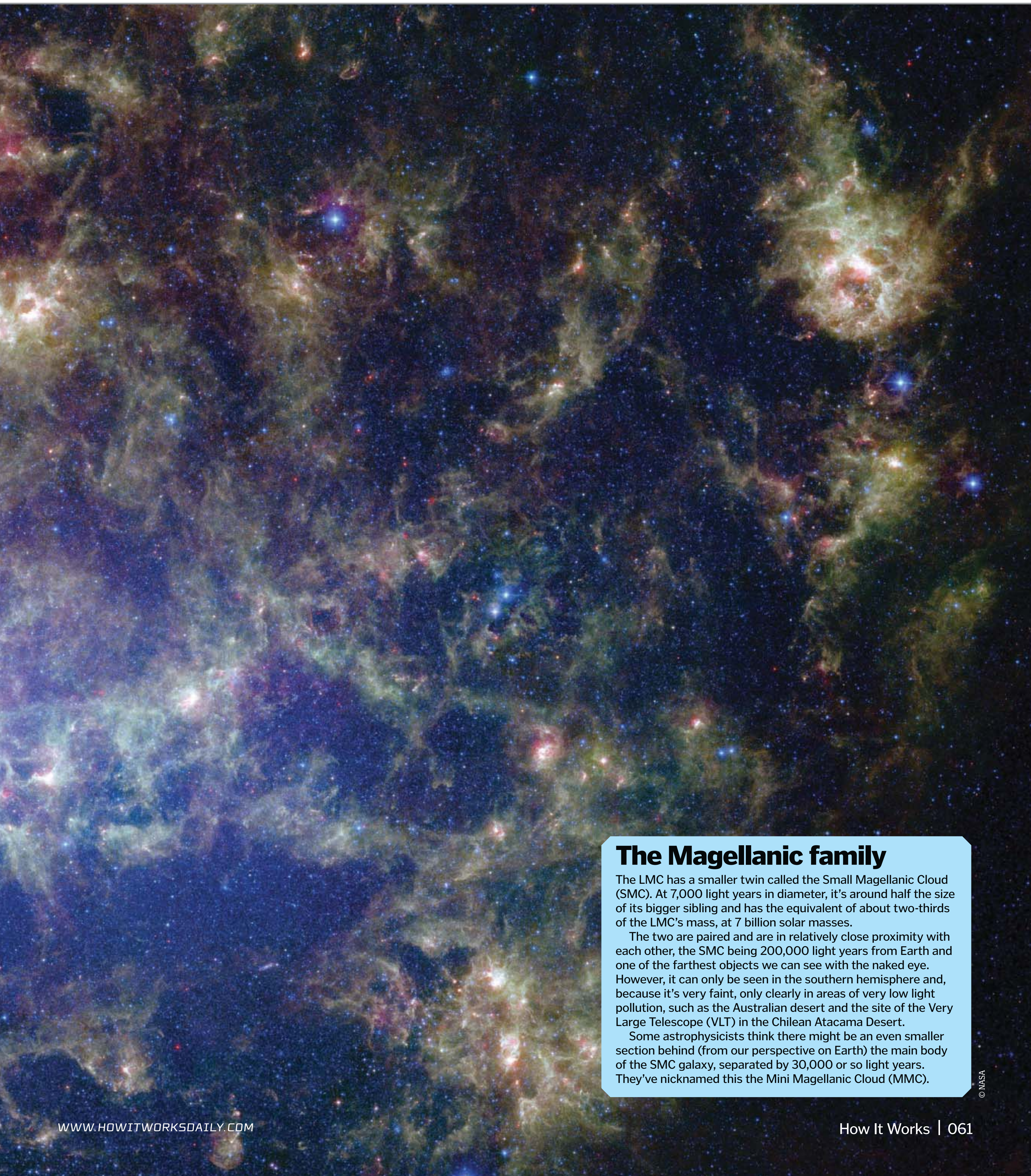
About a million previously unseen objects were discovered in the Large Magellanic Cloud as a result. The blue glow from the centre of the galaxy is light from older stars, while massive hot stars surrounded by dust from their own coronal ejections appear as bright white-blue spots. The red dots are either ancient stars or distant galaxies, while the greenish-yellow represents relatively cool interstellar gas.

This is much more than just a pretty poster though: astronomers were able to use this composite to quantify how space dust is recycled into stars, then star systems and, ultimately, back into dust again. In this image, you can see space dust being expelled by old stars around the red dots, spread about in the greenish-yellow clouds and being consumed by young stars in the rust-toned clouds.

THE STATS
LMC IN NUMBERS

SOLAR MASSES	10bn	DISTANCE FROM EARTH	160,000LY	PLANETARY NEBULAS	400
YEAR FIRST RECORDED	964	SPITZER LAUNCH DATE	25/8/2003	MASS OF SPITZER	950kg

DID YOU KNOW? *If the whole of the LMC could be seen from Earth, it would cover as much sky as 480 full Moons*



The Magellanic family

The LMC has a smaller twin called the Small Magellanic Cloud (SMC). At 7,000 light years in diameter, it's around half the size of its bigger sibling and has the equivalent of about two-thirds of the LMC's mass, at 7 billion solar masses.

The two are paired and are in relatively close proximity with each other, the SMC being 200,000 light years from Earth and one of the farthest objects we can see with the naked eye. However, it can only be seen in the southern hemisphere and, because it's very faint, only clearly in areas of very low light pollution, such as the Australian desert and the site of the Very Large Telescope (VLT) in the Chilean Atacama Desert.

Some astrophysicists think there might be an even smaller section behind (from our perspective on Earth) the main body of the SMC galaxy, separated by 30,000 or so light years. They've nicknamed this the Mini Magellanic Cloud (MMC).

The London Underground

On its 150th birthday, How It Works takes a closer look at one of the most advanced and complex subterranean rail networks on the planet

The London Underground – more commonly known as the Tube – is a sprawling subterranean rail network that comprehensively connects the London metropolitan area. Extending from the reaches of Greater London and beyond into the centre of the bustling metropolis, the Underground is a crucial part of the region's transportation network, carrying over a billion people every year in, out and around Britain's capital.

The Tube consists of a total 270 rail stations over a network that stretches just over 400 kilometres (250 miles) in length. Of that, 45 per cent consists of underground tunnels, which run beneath the many roads, buildings and rivers above, up to a depth of 58 metres (190 feet) below the surface.

This main network is split into 11 interconnecting lines: the Bakerloo, Central, Circle, Hammersmith & City, District, Jubilee, Metropolitan, Northern, Piccadilly, Victoria and the Waterloo & City. These lines each serve a distinct area of the city and surrounding regions – although they do cross over at particularly high-traffic stops – playing host to a fleet of over 4,000 electric multiple unit (EMU) trains.

Tube trains consist of six to eight electrically powered carriages, each linked in sequence. Individual carriages are referred to as EMUs as no separate locomotive is required to pull them – as typically used on overground rail networks – with electric traction motors installed on the majority of units. Electricity for the traction motors comes courtesy of a

5 TOP FACTS
TUBE TRIVIA

Making history
1 The world's very first subterranean railway, the Metropolitan line, opened on 9 January 1863. On its first day of operation, 40,000 people reportedly travelled on it.

Runaway success
2 In light of the successful integration of the Metropolitan line, over 250 different proposals for additional Underground lines had been submitted by 1864.

Going loco
3 The first Underground trains were steam locomotives, which burned coke and coal. This fuel led to sulphurous fumes being emitted into the tunnels and stations.

Safe and sound
4 During both World War I and World War II, disused London Underground lines were used as safe storage sites for a number of valuable artefacts from the British Museum.

Billion
5 As of 2013, the London Underground carries over 1 billion passengers per year across 402 kilometres (249 miles) of track, with 270 station stops.

DID YOU KNOW? *The highest station above sea level is Amersham, north-west of London, at 147m (482ft)*

relatively uncommon four-rail track system where two standard gauge rails act as the carriages' running rails, while a third carries the positive current at +420 volts DC and an inner fourth rail serves as the negative return at -210 volts DC. Ultimately this provides a total supply voltage of 630 volts DC.

The speed at which the EMU Underground trains travel is generally dictated by the distance between each line's stations, with the closer-together inner city stops only permitting top speeds of 48-64 kilometres (30-40 miles) per hour. On lines that stretch farther out of the city centre, with wider gaps between stations, however, speeds of 80-97 kilometres (50-60 miles) per hour are possible.

The London Underground network is accessed through dedicated stations or others located below overground stations. They are reached by escalators, lifts and stairwells from surface level, with a station's platform then accessible via automated ticket barriers. The depth of both station and platform varies, with some a few metres below street level, and others – such as the inner city Bank station – located 40-plus metres (130 feet) down.

It is the depth of large sections of the London Underground that has meant a series of advanced cooling systems had to be fitted to counteract extreme heat buildup in the summer months. To give some perspective, during heat waves temperatures have been recorded in excess of 40 degrees Celsius (104 degrees Fahrenheit)! Solutions include carriage-based air conditioning, station groundwater cooling units and ventilation shafts – all of which help to counter the heat created by the environmental temperature, human bodies and mechanical operations.

Today the Underground is operated by Transport for London (TfL), which oversees almost all aspects of its maintenance, day-to-day running and general improvements. One of TfL's more recent enhancements was the introduction of the Oyster electronic ticketing system in 2003. These credit-card sized contactless devices allow commuters to bypass queues for traditional paper tickets and can also be topped up from your bank account automatically. Proving a huge success, Oyster cards now account for 80 per cent of journeys on London's public transport network.

Where did it all begin?

Arguably, the London Underground only came into existence due to the efforts of just one man. Charles Pearson, a solicitor in London, proposed that the city's rapidly increasing congestion above ground could be eased by expanding on the Thames Tunnel and creating a network of subterranean lines.

Despite opposition, Pearson fiercely defended the concept and, after ten years of debate and discussion from 1850 onwards, Parliament finally approved Pearson's plan and authorised the construction of a six-kilometre (3.8-mile) stretch of underground railway running between Farringdon Street and Bishop's Road (Paddington). Work began in 1860 and used the pre-existing cut-and-cover method of tunnel building where trenches were marked and dug along city streets, lined with brick walls, covered with an arch roof and then topped with a new roadway.

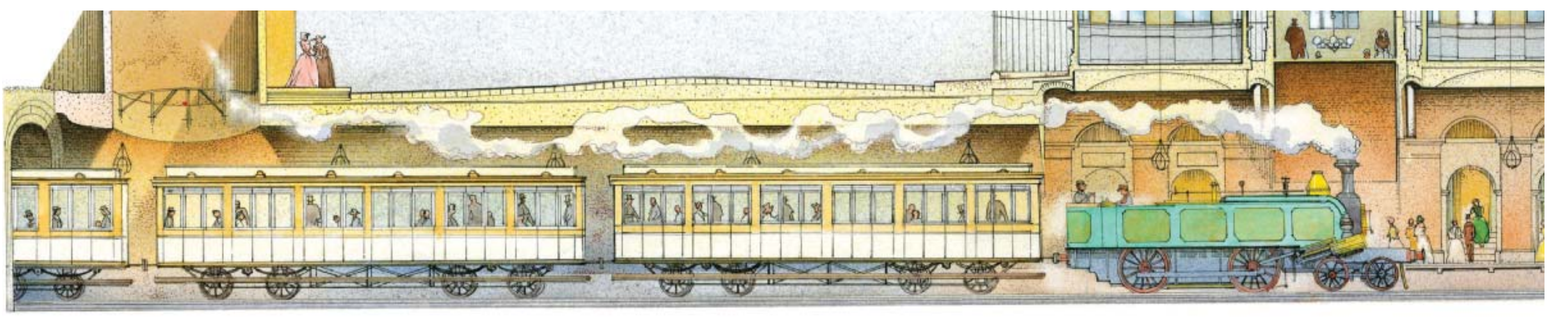
After three years of construction, this relatively short stretch of track was finally opened to the public on 9 January 1863, becoming the world's very first underground rail passage and the London Underground's first line: the Metropolitan.

How are the Tube's tunnels built today?

While historically the Underground's tunnels were constructed through primitive manual labour, today huge 1,000-ton, 150-metre (490-foot)-long tunnel-boring machines (TBMs) do most of the hard graft. Each machine has a rotating cutterhead at the front and a long series of trailers behind that hold all the mechanical and electrical equipment. The cutterhead rotates at approximately three revolutions per minute, carving set diameter tubes out of the clay, sand and gravel situated under much of London.

Interestingly, unlike other tunnel-building projects through more rural terrain, in London all manner of obstacles need to be taken into consideration and bypassed. These include other Underground lines, utility supplies, sewer systems and even hidden subterranean rivers that run down to depths of 40 metres (130 feet) below the surface. For this reason, extensive geophysical maps of the project area are created both before and during an excavation.

Once the Tube tunnel is built, it is lined with concrete and then installed with the electrical cabling and support systems that will power the line's lights and ventilation systems.



Tube timeline

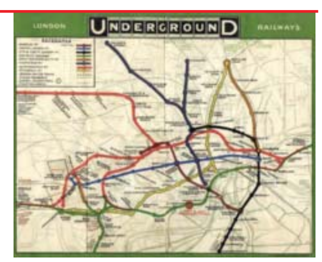
HIW highlights some of the key developments in the evolution of the London Underground

1863
Debut
The Metropolitan Railway opens the world's first underground line.

1870
Below the Thames
Near the Tower of London a tunnel under the Thames is opened. It is the first Tube tunnel to be built using a tunnelling shield.

1890
A great lift
The first hydraulic lift access to a London Underground station is completed.

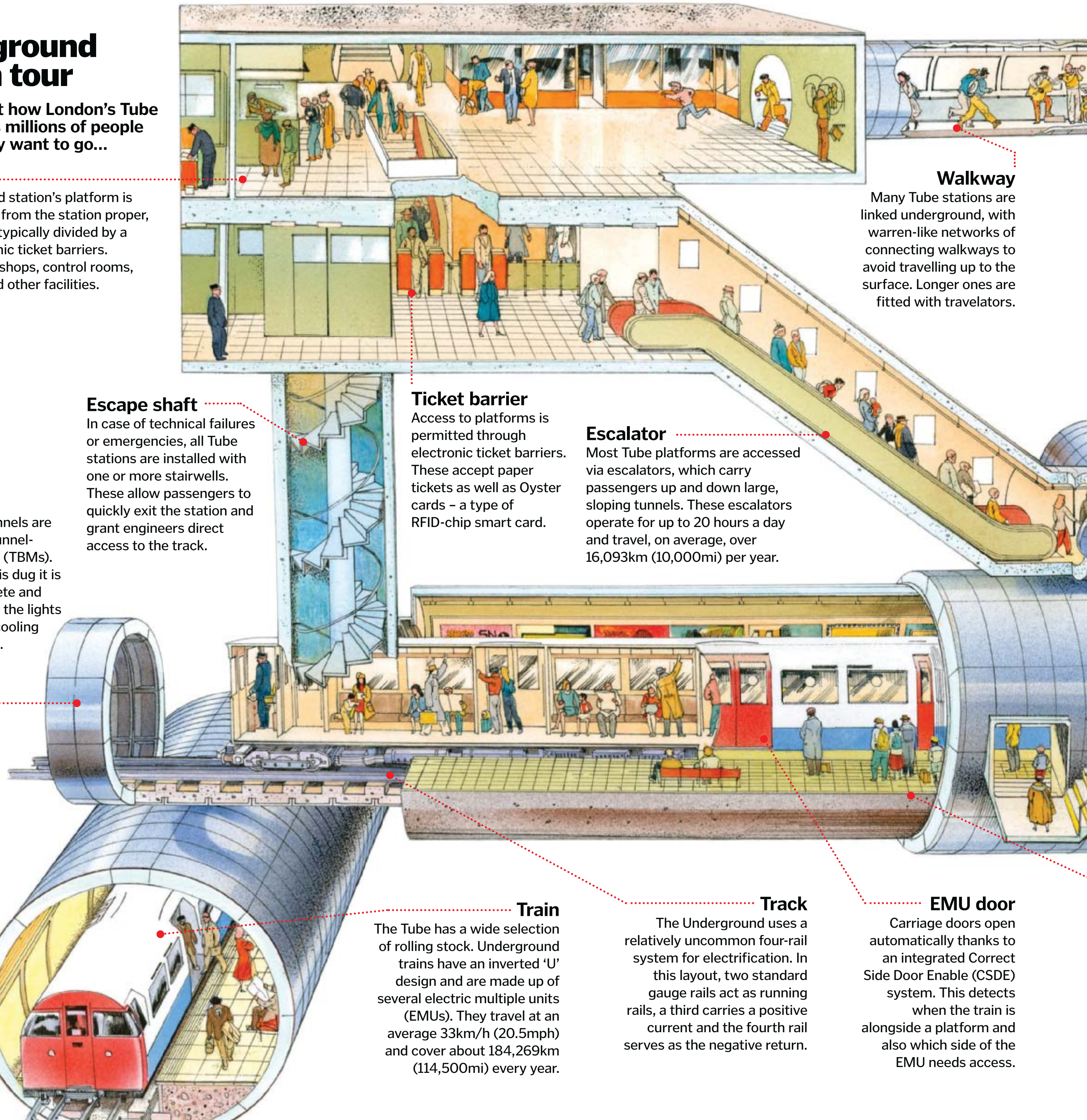
1908
All mapped out
The first combined map of the Tube is published by the Underground Electric Railways Company of London. This map showed eight lines in total.



"Escalators operate for up to 20 hours a day and travel, on average, over 16,093km (10,000mi) per year"

Underground station tour

Take a look at how London's Tube network gets millions of people to where they want to go…



Station
The Underground station's platform is usually separate from the station proper, and the two are typically divided by a series of electronic ticket barriers. Stations feature shops, control rooms, ticket offices and other facilities.

Walkway
Many Tube stations are linked underground, with warren-like networks of connecting walkways to avoid travelling up to the surface. Longer ones are fitted with travelators.

Escape shaft
In case of technical failures or emergencies, all Tube stations are installed with one or more stairwells. These allow passengers to quickly exit the station and grant engineers direct access to the track.

Ticket barrier
Access to platforms is permitted through electronic ticket barriers. These accept paper tickets as well as Oyster cards – a type of RFID-chip smart card.

Escalator
Most Tube platforms are accessed via escalators, which carry passengers up and down large, sloping tunnels. These escalators operate for up to 20 hours a day and travel, on average, over 16,093km (10,000mi) per year.

Tunnel
Modern Tube tunnels are dug with giant tunnel-boring machines (TBMs). Once the tunnel is dug it is lined with concrete and cabling to power the lights and ventilation/cooling systems is fitted.

Train
The Tube has a wide selection of rolling stock. Underground trains have an inverted 'U' design and are made up of several electric multiple units (EMUs). They travel at an average 33km/h (20.5mph) and cover about 184,269km (114,500mi) every year.

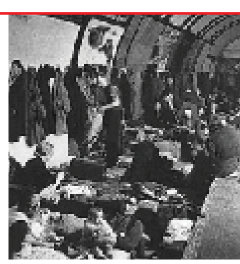
Track
The Underground uses a relatively uncommon four-rail system for electrification. In this layout, two standard gauge rails act as running rails, a third carries a positive current and the fourth rail serves as the negative return.

EMU door
Carriage doors open automatically thanks to an integrated Correct Side Door Enable (CSDE) system. This detects when the train is alongside a platform and also which side of the EMU needs access.

1925
Electrified
Electrification of the Metropolitan line is extended out of London's city centre.

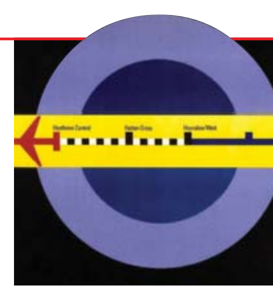
1938
Stock
The now famous 1938 rolling stock (trains) is introduced by the Underground's chief engineer.

1941
Wartime shelter
During the Blitz in WWII, London civilians take shelter from German air raids in Tube stations and tunnels (right).



1968-69
Digital age
The Victoria line opens between Walthamstow Central and Victoria. It is the world's first computer-controlled railway.

1977
Flying high
The Underground finally links to the city's main airport, Heathrow Central, via the Piccadilly line.



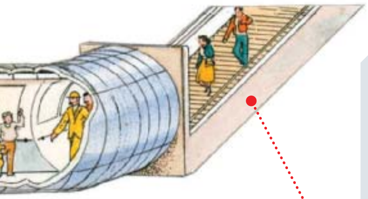
HEAD 2 HEAD
LEARN YOUR LINES

1. LONG — Circle
Measuring 27.2 kilometres (17 miles), the Circle line goes around central London and features 35 stations. It's coloured yellow on the Tube map.

2. LONGER — Piccadilly
First opened in 1906 and 71 kilometres (44.3 miles) in length, the Piccadilly line boasts 52 stations and runs into London from the north-east.

3. LONGEST — Central
Measuring 74 kilometres (46 miles), the Central line is technically London's longest Underground line. It was opened in 1900 and has 49 stations.

DID YOU KNOW? *The Tube's well-known bar and circle logo – known as the roundel – first appeared in 1908*



Entrance
The Tube network is accessed from the surface – in the main – by signed stairwells. These either lead directly into the station itself or into road/building underpasses. Many overground stations have internal entrances to partnering Tube stations.

Platform
Brick and concrete platforms line one or both sides of the track. These are marked with yellow safety lines to prevent accidents. The platforms tend to have some seating, maps and electronic help points.

Art and design on the Underground

For decades the London Underground was renowned for advertising its services through the medium of posters, with many famous artists – such as Edward McKnight Kauffer and Paul Nash among others – being commissioned to produce colourful canvases. The Tube still advertises in this way, commissioning posters each year to promote key improvements and events. Today, as part of the Underground's 150-year anniversary, the London Transport Museum is displaying 150 of its 3,300 posters, with many of the most famous works plus a few rarer, lesser-known examples. On display until 27 October 2013, for more information about the exhibition, visit **www.ltmuseum.co.uk**.

The future of the Tube

One of the biggest developments in London's transport system right now is the introduction of the Crossrail line. While not technically part of the Tube, the Crossrail will be integrated with it, adding an additional 21-kilometre (13-mile) line across the city from east to west.

The London Underground itself, however, is currently undergoing a major renovation project of its own, increasing the size and access points to stations, adding extra rolling stock to each line, extending many pre-existing lines and even introducing Wi-Fi zones. Indeed, over 100 stations throughout the Underground network are already installed with Wi-Fi hotspots, allowing those travelling on the Tube to access the internet even when deep underground.


Tottenham Court Road is just one of many stations being overhauled as part of the Crossrail project

London Underground by numbers

1.107bn people use the London Underground each year

82mn passengers enter Waterloo Tube station annually

19,000 people work on the Tube

60m Length of the network's longest escalator, which is found at Angel station

4,134 EMUs in the entire fleet

27.8km Longest continuous tunnel length

270 stations served by the LU

55.2m Deepest lift shaft

426 escalators installed

1980
LTM opens
After the Covent Garden Market moves in 1971, the London Transport Museum (right) opens in its place nine years later. It's still a very popular attraction today.

1987
King's Cross ablaze
A major fire on one of the wooden escalators at King's Cross Underground station kills 31 people.

2003
Oyster
Oyster payment cards are introduced, allowing speedy access and automatic top-ups.

2013
The big 150
The London Underground celebrates its 150th anniversary.

"In some supersonic aircraft, such as fighter jets, a fuel dump can be ignited using the afterburner"

Inside car batteries

Learn about the power hubs our cars couldn't do without

The vast majority of car batteries are part of the lead-acid battery group, where they fall into the SLI category. SLI stands for 'starting-lighting-ignition' – a reference to what the device is responsible for within a vehicle; in other words, it not only powers the car's starter motor but the ignition and lighting systems too.

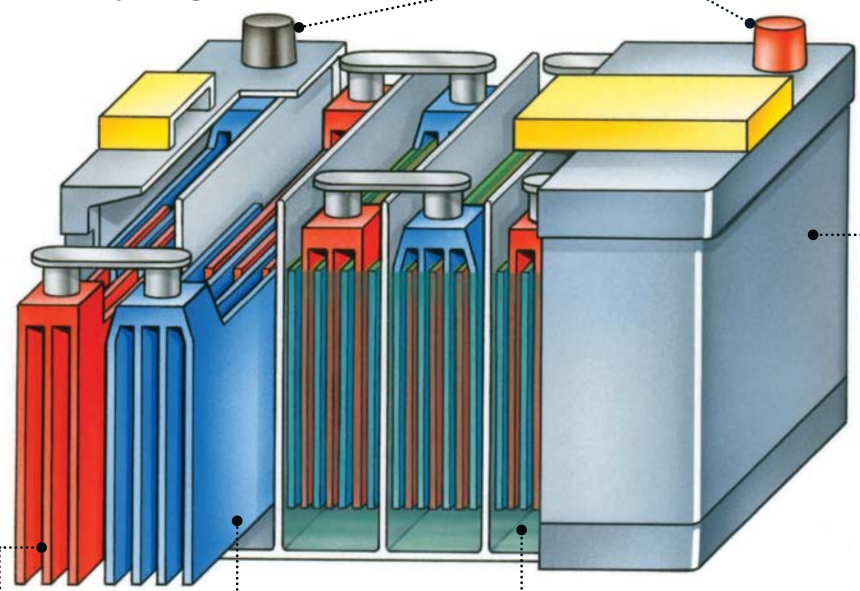
SLI batteries constitute six galvanic cells – see the 'Anatomy of a car battery' diagram for details – laid out in series. Each cell delivers 2.1 volts of electromotive force that, when combined, produce a 12.6-volt SLI battery (commonly advertised as 12-volt). One of these 12-volt batteries is powerful enough to keep a car's systems running for years, though larger diesel vehicles may employ two.

Each galvanic cell consists of a series of lead and lead dioxide plates which are submerged in an electrolyte solution – a mix of sulphuric acid (35 per cent) and water (65 per cent). This acidic bath triggers a reaction with the lead dioxide plate (the positive electrode) which produces ions and lead sulphate. These sulphuric ions then react with the adjacent lead plates (the negative electrode) to produce hydrogen ions and lead sulphate. This chemical reaction, in turn, generates electrons that can flow out via conductive terminals as electricity to power essential functions.

The reaction is not permanent, with the lead sulphate reforming into lead dioxide and lead when the battery is recharged. Over time, the battery's efficiency will deplete, with most working optimally for about four years.

Anatomy of a car battery

Check out the key elements of a vehicle's power generator



Terminals
This is where energy leaves the galvanic cell array. They are made of lead – a good, corrosion-resistant conductor.

Casing
The six galvanic cells are held in position by a non-reactive plastic composite case.

Lead plate
The negative electrode reacts with sulphuric ions to generate hydrogen ions and more lead sulphate.

Lead dioxide plate
This is the active material within the battery, reacting with the acid to produce ions and lead sulphate.

Sulphuric acid
Plates are submerged in acid which acts as the chemical catalyst and an electrolyte for ions.

Understanding fuel dumps

Why do planes sometimes eject their fuel and set it alight while mid-flight?

Many aircraft have valves that allow them to dump fuel from their tanks in an emergency. This is because the vast amount of aviation fuel that some planes require for long-haul flights adds significantly to their overall weight. The passenger aircraft Airbus A380-800, for example, has a maximum fuel capacity of 320,000 litres, which is nearly 300 tons extra for a plane weighing 280 tons when empty anyway!

While taking off with such a substantial burden is safe, aeroplanes usually have a much lower maximum landing weight. So, if for any reason the aircraft has to make an emergency landing, a built-in dump valve allows it to empty the fuel tanks as much as possible while in the air.

In some supersonic aircraft, such as fighter jets, a fuel dump can be ignited using the afterburner, resulting in a huge burst of flame – known as 'dump-and-burn' – but this serves no purpose other than to wow spectators.

The Royal Australian Air Force's F-111 fighter bombers were once famous for their dump-and-burn displays but have now been retired

> "Large tracked wheels, reinforced pivot frames and high-torque motors allow for cross-country use"

Electric wheelchairs

How do these modern mobility vehicles get people from A to B?

Electric wheelchairs are an evolution of the traditional hand-pushed wheelchair/bath chair. They function in much the same way as manual wheelchairs, granting mobility to users over a wide range of terrains and inclines, however they're self-propelled, with a motor doing the hard graft.

As the chair is motorised, they also differ to manual wheelchairs in that they feature a systems platform beneath the seat. This platform – which is typically encased within a plastic shell – supports the motor as well as its power source (typically a battery array). The power pack is then connected via a wiring system to the motor, the seat and the wheelchair's all-important control panel.

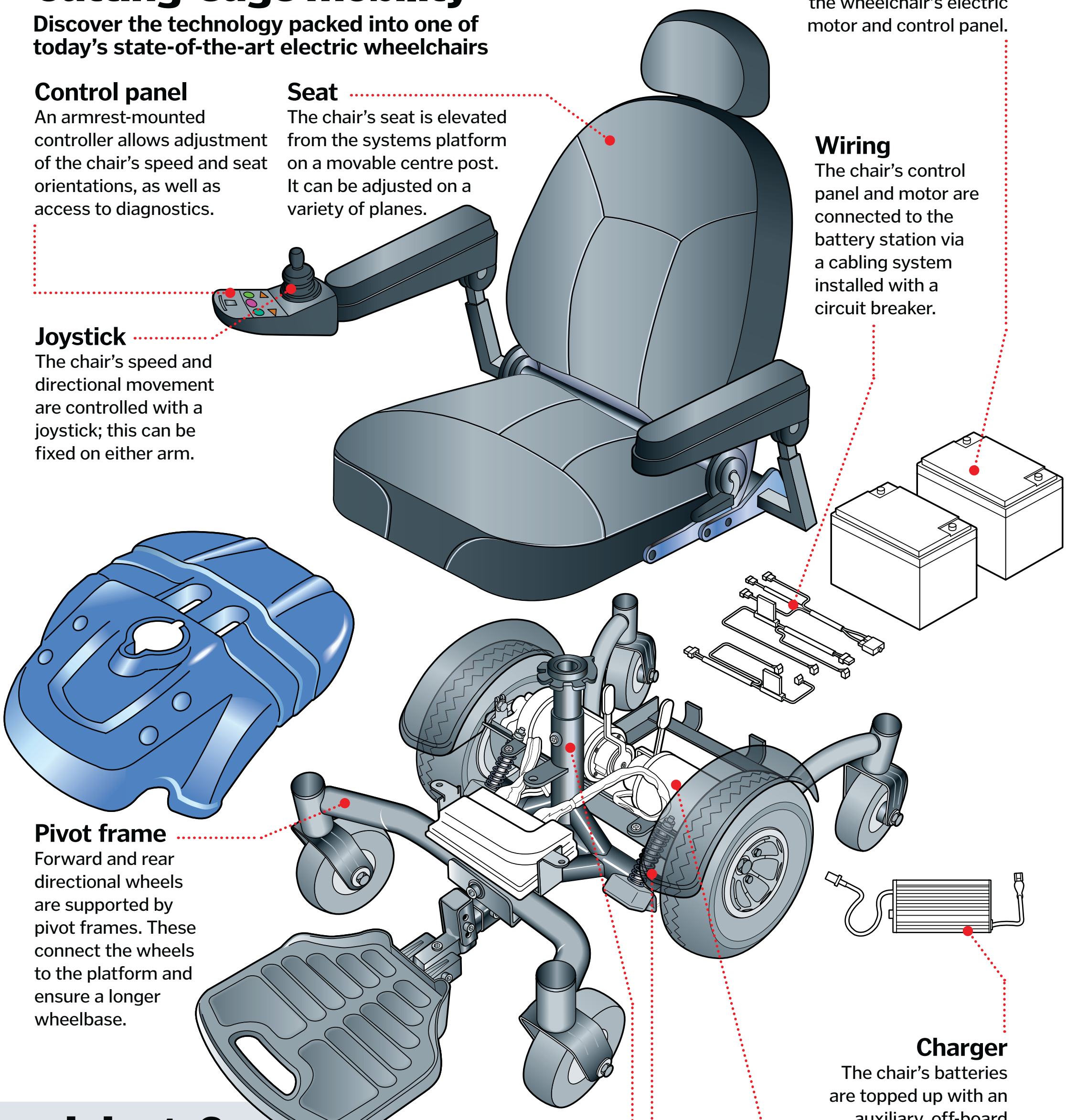
These controls, which are generally located on one of the armrests, enable the user to operate the majority of the chair's functions. These include seat position (both elevation and tilt), motor power for speed alterations, directional movement – delivered through a joystick, plus system diagnostics.

Drive wheels on electric wheelchairs, unlike manual models, are fixed on a single plane, with an additional set, or pair of sets, found at the front and back of the chair to take care of guidance. These guide wheels are typically fitted with variable suspension struts and springs so the wheels remain in contact with the ground even on uneven surfaces.

Indeed, many modern electric wheelchairs are designed to cope with robust terrains, with large tracked wheels, reinforced pivot frames, pneumatic suspension units and high-torque motors allowing for cross-country use.

Cutting-edge mobility

Discover the technology packed into one of today's state-of-the-art electric wheelchairs



Control panel
An armrest-mounted controller allows adjustment of the chair's speed and seat orientations, as well as access to diagnostics.

Seat
The chair's seat is elevated from the systems platform on a movable centre post. It can be adjusted on a variety of planes.

Power
Two 36-amp batteries are installed at the rear of the systems platform powering the wheelchair's electric motor and control panel.

Wiring
The chair's control panel and motor are connected to the battery station via a cabling system installed with a circuit breaker.

Joystick
The chair's speed and directional movement are controlled with a joystick; this can be fixed on either arm.

Pivot frame
Forward and rear directional wheels are supported by pivot frames. These connect the wheels to the platform and ensure a longer wheelbase.

Charger
The chair's batteries are topped up with an auxiliary, off-board charging unit. This is plugged into a mains electricity port.

Seat post
The seat post sits in the middle of the systems platform and allows for a maximum weight capacity of 136kg (300lb).

Suspension
Coil spring tension suspension units – both of which are adjustable from the control panel – prevent the wheels from losing purchase on the ground.

Motor
An electric drive motor powers the chair's twin drive wheels, allowing a max speed of 6.4km/h (4mph) and a max range of about 30km (18.6mi).

Where did wheelchairs originate?

While wheeled platforms are recorded dating back to the 6th century BCE, one of the earliest references to wheelchairs being used in their modern incarnation comes from the 6th century CE. These are depicted in Chinese art carrying children, invalids and even emperors. These manually pulled cart-style chairs, however, were only the preserve of the rich and powerful, with wood, metal and those able to make them all in short supply. A good example of this can be seen in the inset image, which shows famous Chinese politician and philosopher Confucius being pushed around in his own bespoke wheelchair.

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> "The wings and tail are built high to allow the freight to sit near the ground and to facilitate loading"

On board a cargo plane

How do freight aircraft differ from passenger planes, enabling them to transport much greater loads all over the planet?

Cargo planes – whether used in the private, military or commercial sphere – are fixed-wing vehicles that have usually been designed with haulage in mind or have been converted from standard aircraft. Passenger planes commonly have a specialised hold that can store around 150 cubic metres (over 5,000 cubic feet) of freight, found on the underside of the craft. Dedicated freight planes don't need the seats or any of the other amenities on commercial flights – that said, their design amounts to much more than a hollowed-out passenger plane.

To make the most efficient use of the space available, the floor is lined with a walkway and electronic rollers that allow prepackaged pallets to be rolled back as far as possible, without the need for a forklift. Large cargo bay doors are installed to fit bigger items through and, in some examples, like the Boeing 747-400, the nose lifts up to allow particularly large items to pass down the body of the plane. With the demands of air freight ever increasing, aircraft with huge cargo capacities like the Airbus A300-600 Super Transporter (also known as the Beluga), are becoming the norm.

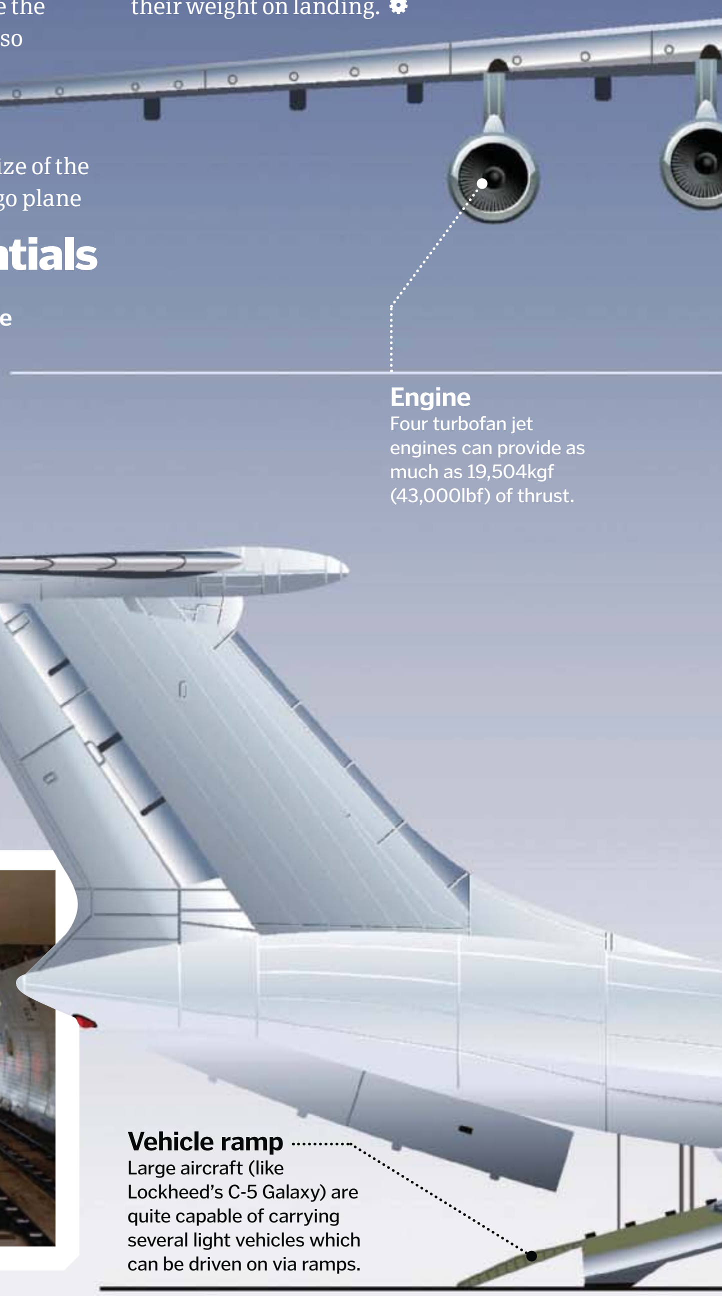
It's not enough just to increase the size of the aircraft hold though. In order for a cargo plane to efficiently and safely transport its mighty load, a number of adaptations must be made to the overall avian design. For example, the wings and tail are built high to allow the freight to sit near the ground and to facilitate loading; the fuselage is much bigger; and – similar to heavy goods vehicles – cargo planes typically feature a larger number of wheels to support their weight on landing.

Plane politics

The Xian Y-20 is a military long-range transport plane that's still in development by China, although it has recently been filmed on a short test flight. It's a similar class of aircraft as Russia's Ilyushin Il-76 or the US Boeing C-17, and though China maintains a tighter guard over its military secrets than most, it has an estimated payload in the region of 72,000 kilograms (160,000 pounds) – that's quite a bit, by any country's standards! The PLAFF (People's Liberation Army Air Force), or avian branch of the Chinese military, had long favoured the development of fighter jets over this kind of support aircraft, so that the Y-20 project was sidelined when it started in 2005. However, following the Sichuan earthquake of 2008, China was unable to effectively drop relief supplies with its small fleet of cargo planes, so the US had to assist with two C-17s. This embarrassment undoubtedly spurred the Chinese government into pushing on with the Y-20's development.

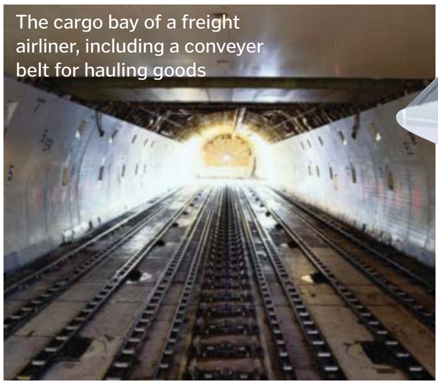
Cargo plane credentials

HIW pinpoints what a military cargo transporter needs to get the job done



Lightening the load

Depending on the type of cargo being carried (very large items or military vehicles may be exceptions), many cargo planes will use ULDs, or unit load devices. These allow the crew to prepackage cargo into single units that can more easily be loaded into the hold prior to the flight, saving a great deal of time. It's a similar system to that used in shipping, maximising the space used at the same time and, thus, increasing efficiency (and profits). The ULDs themselves are either robust and lightweight aluminium pallets or aluminium-floored containers with toughened plastic walls. The containers are sometimes converted into self-contained refrigeration units to store perishable goods.


The cargo bay of a freight airliner, including a conveyer belt for hauling goods

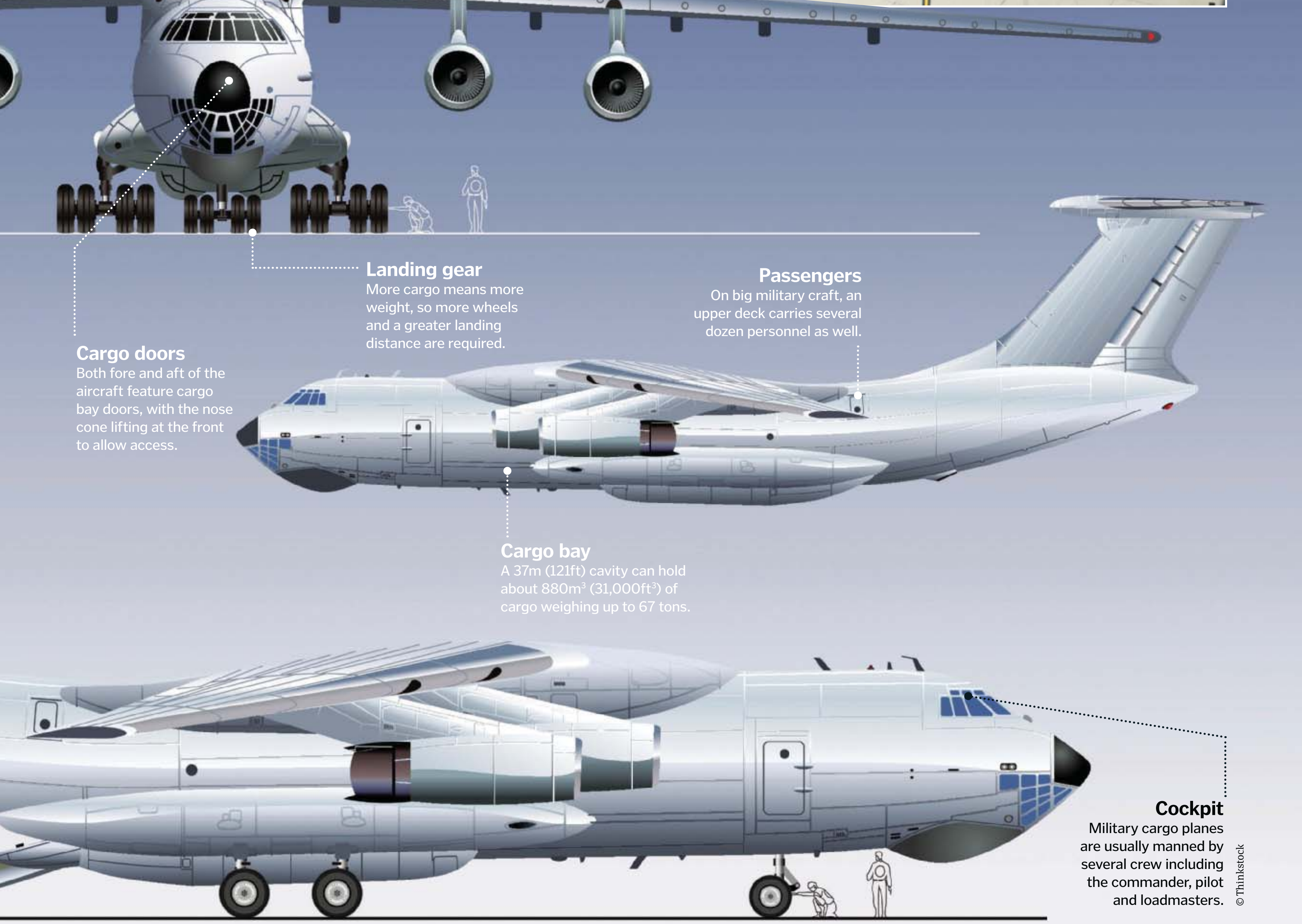
250 tons

WORLD'S BIGGEST CARGO PLANE

This title goes to Russia's Antonov An-225 Mriya. It has a wingspan roughly the length of a football pitch, can carry four tanks in its cavernous hold and has space for up to 80 cars.

DID YOU KNOW? *Passenger planes have been used to carry mail since 1911 and still do to this day*

Lockheed Martin's C-5 Galaxy has 12 internal wing tanks with a total capacity of 194,370l of fuel



KEY DATES
VIKINGS IN ENGLAND

793 CE
The first recorded Viking raid on England at the monastery on the island of Lindisfarne.

871
King Alfred of Wessex defeats the Vikings in battle, but concedes large parts of eastern England.

886
North England is almost entirely conquered. All vanquished regions are subject to Danelaw.

1016
Canute the Great becomes king of England after a year and a half of conflict.

1066
After decades of decline, the Vikings' influence in England wanes, culminating in the Norman invasion.

DID YOU KNOW? *The word 'Viking' means 'pirate' in early Scandinavian languages*

AGE of the VIKINGS

Learn how treasure, trading opportunities and an insatiable hunger to explore drove this Norse people to build a vast empire

Vikings were Scandinavian seafaring warriors who, throughout the eighth, ninth and tenth centuries, terrorised large swathes of Europe. While at home in Norway, Denmark and Sweden the Viking people were largely independent farmers operating under land-owning chieftains, while abroad they were ruthless opportunists, pillaging lands of their riches in fearsome raids. From the northern reaches of England and Scotland to as far afield as Constantinople (modern-day Istanbul) and the Americas, no civilisation was safe.

While cross-land raids were frequent, the Vikings became most known for their cross-sea raiding parties, with powerful longships carrying bands of warriors around the seas of Europe – and beyond – in a series of fearsome lightning-strike offensives. This type of high-speed, undetected attack was what the Vikings specialised in, typically choosing targets that were relatively undefended and then sacking them in a brutal hit-and-run. Any loot was then immediately loaded back onto their longboats and returned to their native country, often with nothing more than the smouldering remains of the settlement revealing the Vikings had ever been there.

Of all the nations in Europe it was arguably England that bore the full brunt of the Vikings' taste for raiding by sea, with a succession of blitz raids and full-on invasions occurring from the late-eighth century right through to the early-11th century. These led to vast areas of England being taken by the Vikings and numerous clashes with the native rulers. One of the most notable of these was Anglo-Saxon King of Wessex, Alfred the Great. Alfred saw the kingdoms of East Anglia, Northumbria and Mercia captured by the Vikings and only through a treaty and then further conflict did he halt the expansion of the Danelaw (Viking societal rules) and their territories.

Interestingly, however, while the age of the Vikings was characterised in western Europe by military conquest, in the east it was typified by trade. Indeed, while there is evidence of sporadic raiding in the Baltic region, no Viking presence was ever enforced here via the sword. In contrast, Viking expeditions into Russia, Turkey and Greece opened up previously non-existing trade routes and commercial revenue streams, with many products, materials and techniques from other cultures returned to Scandinavia.

The Vikings' dominion came to an end in the 11th century. This was caused by a variety of factors, but none more so than their geographic and cultural dispersion. In making expeditions and raids throughout the world – ranging from Newfoundland to Byzantium – foreign culture, religion and practices were carried back to Scandinavia, all of which had a significant influence on the Norse inhabitants. While in the eighth century Vikings were largely poor pagan people living off the land and ruled by chieftains across a host of segmented kingdoms, by the late-11th century Denmark, Norway and Sweden were becoming unified countries, Christianity had taken root, towns had been transformed into administrative centres and market sites, and established royal dynasties had emerged. By the 12th century the marauding way of life was simply no longer popular – or indeed necessary.

Today, the influence of the Viking era is marked. Many modern towns and cities can trace their roots to Vikings (such as Scarborough in northern England), while many words that are now in common use were introduced from the Old Norse tongue. For example, 'bag' stems from the Old Norse word 'baggi'). Further, studies of genetic diversity have shown that many individuals today across the planet possess the Y chromosome haplogroup I-M253, which is a strong indicator of Scandinavian descent.

"Multiple bands of 25-40 warriors would have undertaken the raid, armed with axes, swords and spears"

Lindisfarne under attack

See how the infamous 793 CE raid on Holy Island off the Northumbrian coast played out

3. Approach
The raid was launched so the Vikings would approach the island in June. This summer arrival was planned as the season's good weather made passage across the sea easier.

4. Landing
The raid commenced on 8 June, with longships approaching the monastery from the island's natural bay to the south-east of the complex. The boats were hauled up onto the pebble beach.

5. Warriors
While the number of raiders is unknown, multiple bands of 25-40 warriors would have undertaken the raid, armed with axes, swords, spears and daggers. Monks were cut down, drowned or taken prisoner.

6. Tactics
Tactically, Viking raids were quite chaotic. While when fighting rival military bands some basic tactics were employed – such as shield walls and wedge formations – on Lindisfarne warriors merely charged the monastery.

7. Monastery
The Lindisfarne monastery was established in the early-seventh century and had grown to become the main site of Christian evangelism in northern England. By the time of the raid, it was a large complex including religious, industrial and domestic buildings.

8. Loot
Due to Christianity's growing dominance in western Europe at the time, Lindisfarne was packed full of gold, silver and religious artefacts. These were the primary target for the Vikings.

9. Monks
The tenants of the monastery were Christian monks. While rudimentary weapons or tools were available, the monks' pacifist lifestyle and lack of military training gave them little chance of defending themselves.

1. FAMOUS

Harald Hardrada
The first ruler of Norway to ensure his heir's succession to the throne, Hardrada was an atypical pirate and celebrated Viking king.

2. MORE FAMOUS

Ragnar Lodbrok
While only sovereign of Denmark and parts of Sweden briefly, Lodbrok was a superb military commander and during a raiding trip in 845 CE he sacked Paris.

3. MOST FAMOUS

Canute the Great
King of England, Denmark, Norway and some of Sweden, Canute (or Cnut) was probably the most successful Viking ruler.

DID YOU KNOW? *In their native lands Vikings were independent farmers*

10. Return
After all the monks had been slain or captured – although a limited few did escape – and the site had been pillaged and largely burnt, the Vikings swiftly returned to their vessels to begin the voyage home.

1. Origin
The Lindisfarne Viking raids were launched from Norway and Denmark, with bands of warriors travelling west across the North Sea. The raid had been planned over several months.

2. Longship
Warriors, in addition to a select few craftsmen, made the journey on longships. These vessels allowed voyage over both deep and shallow waters and were well suited to littoral (shore) approaches.

Ready for battle
What weaponry and armour did Viking warriors typically use in combat?

Helmet
Viking helmets were round, peaked caps made of iron plates. They were typically fitted with eye plates and noseguards.

Clothing
Beneath their armour Viking warriors wore tunics and trousers made from wool, linen and animal skins.

Armour
Vikings were not heavily armoured, wearing normally just a mail shirt that extended to the thighs and elbows. This aided mobility in combat.

Shield
Viking shields were circular and made from woods such as lime, alder and poplar. Their size varied from 46cm (18in) through to 122cm (48in).

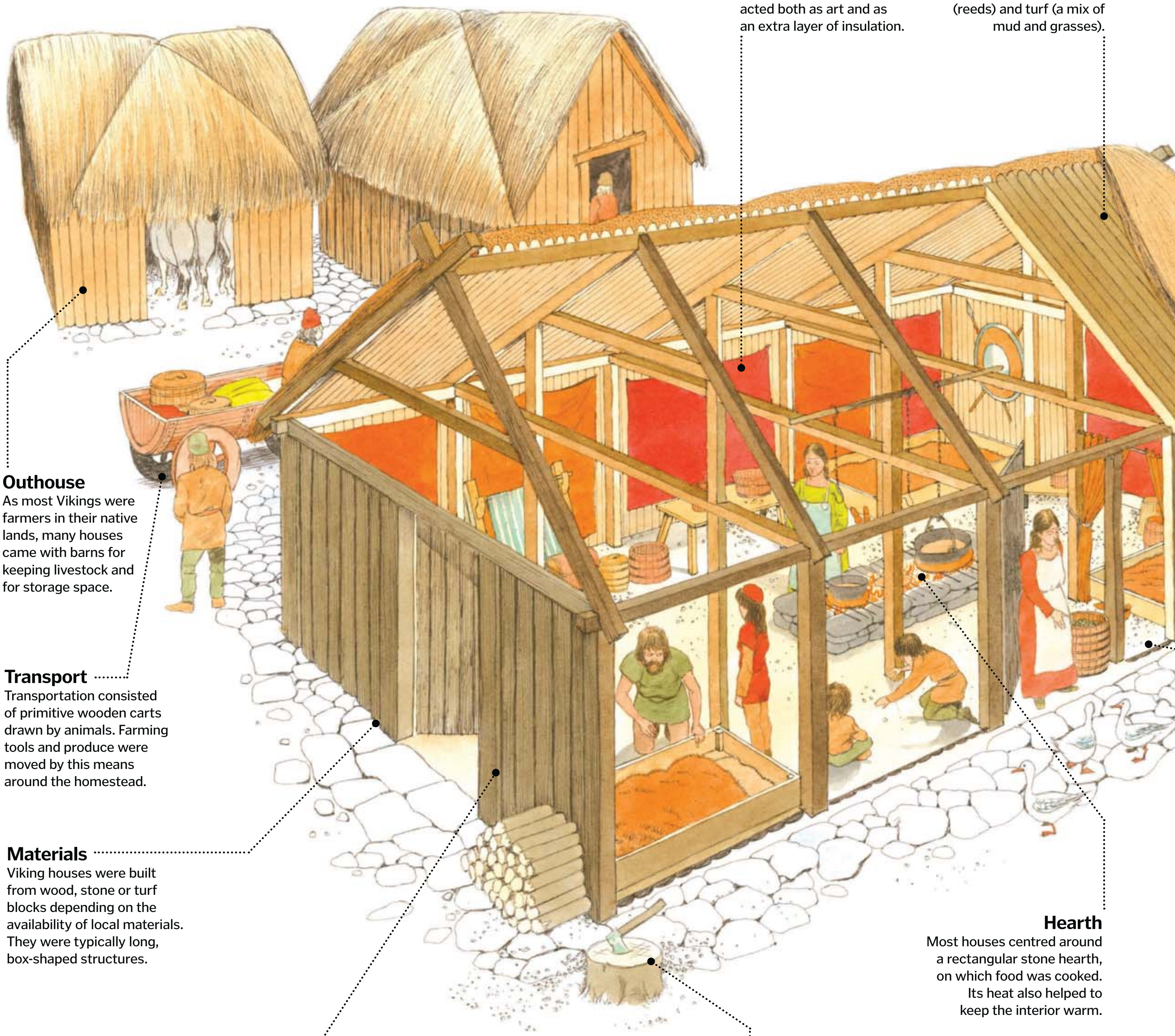
Primary weapon
The axe was the most common Viking weapon, distinguished by its crescent blade shape. Wealthier or more important warriors would carry a sword.

Back-up weapon
In addition to their axe or longsword, most warriors also carried an additional weapon. These ranged from seaxes (a Germanic dagger) through to knives and small spears.

"The concept of the longship in relation to funerals in the Viking age was very strong"

Tour of a Viking homestead

How did these Norse people live when they weren't out warmongering?



Tapestry
Decorative tapestries were hung from the wooden walls. These acted both as art and as an extra layer of insulation.

Roof
The roofs of Viking buildings were made with a combination of thatch (reeds) and turf (a mix of mud and grasses).

Outhouse
As most Vikings were farmers in their native lands, many houses came with barns for keeping livestock and for storage space.

Transport
Transportation consisted of primitive wooden carts drawn by animals. Farming tools and produce were moved by this means around the homestead.

Materials
Viking houses were built from wood, stone or turf blocks depending on the availability of local materials. They were typically long, box-shaped structures.

Walls
The walls of each house were made from wattle, an amalgamation of woven sticks and dried mud. These were clad with wooden beams/planks.

Courtyard
Larger homesteads or farms often featured stone-laid courtyards. Everyday tasks such as chopping wood and tending livestock took place here.

Hearth
Most houses centred around a rectangular stone hearth, on which food was cooked. Its heat also helped to keep the interior warm.

5 TOP FACTS
VIKING MYTHS

Horny issue
1 Aside from a few ceremonial helmets, no Viking helmet has survived that is mounted with horns. This common but inaccurate depiction only arose during the 19th century.

Skull-duggery
2 Another myth commonly believed today is that Viking warriors would use the skulls of their slain enemies as drinking cups. However, no evidence for this exists.

Bath time
3 Vikings were not, as generally depicted, dirty and wild. Indeed, they were considered very clean by Anglo-Saxon standards due to their custom of bathing every Saturday.

East meets west
4 Vikings did not just raid and settle in western Europe but throughout large parts of Asia and beyond. Evidence of occupation has even been found in Turkey.

No more Vikings
5 Despite the age of the Vikings ending in the 11th century, their influence is felt to this day, with many of their words, names, tools and construction techniques still around.

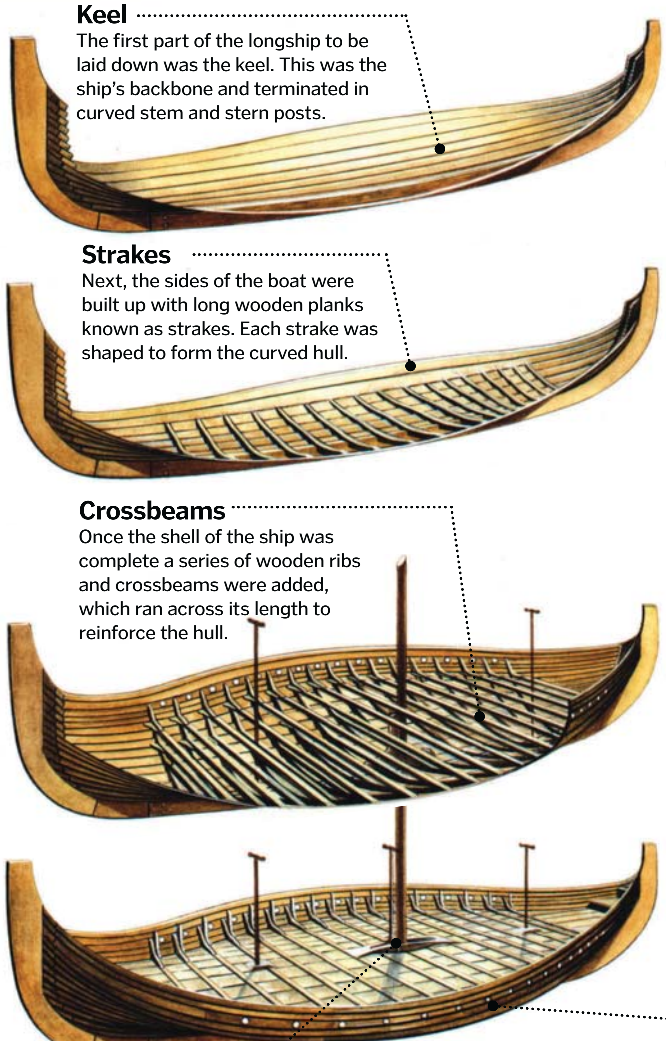
DID YOU KNOW? *Vikings traded in all manner of goods, exchanging things like honey and walrus ivory for silver and spices etc*

Viking fodder

According to evidence discovered at various archaeological sites – such as bones, seeds and other remains – Vikings ate a great deal of domestic and wild meats, as well as foraged foods such as nuts and berries. Meat tended to be either boiled in large stewing cauldrons or roasted on spits directly over the fire. Prior to cooking, some meats – and often fish – were smoked and dried for preservation. Vikings also ate a lot of bread, which was made from rye or barley flour, while they used animal milk to make dairy goods like cheese and butter. Common beverages included ale, mead and buttermilk.

Constructing a longship

HIW breaks down how the Vikings made arguably their most important weapon



Keel
The first part of the longship to be laid down was the keel. This was the ship's backbone and terminated in curved stem and stern posts.

Strakes
Next, the sides of the boat were built up with long wooden planks known as strakes. Each strake was shaped to form the curved hull.

Crossbeams
Once the shell of the ship was complete a series of wooden ribs and crossbeams were added, which ran across its length to reinforce the hull.

Mast-step
Next the mast-step, a large block of wood that supported the mast, was installed in the base and a rudder was attached to the stern.

Oar hole
Holes for the oars were cut into the hull. Vikings sat either side and rowed in unison when winds were low, with up to 20 men per side.

Floor
Due to the relatively primitive nature of building construction, the floors of Viking houses were often recessed to mitigate draughts.

The final journey

Viking burial customs were diverse, with everything from tumuli burials – large earthen tombs – to runestone-marked pits and cremation. One of the most famous practices was the ship burial. This entailed laying the deceased along with grave offerings on a wooden ship – either on land or on water – and then covering it with a huge pile of stones and soil or setting it alight. Interestingly, the concept of the longship in relation to funerals in the Viking age was very strong, with even certain tumuli and runestone markers laid out in a ship pattern. This came from a belief that the deceased were making their final journey to Valhalla – Norse heaven.

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"Since its discovery the complex has been extensively excavated as it was in a ruinous state"

Exploring Machu Picchu

Perched precariously between two Peruvian peaks, the ancient Incan complex of Machu Picchu is truly one of Earth's wonders

Machu Picchu is a world-famous 15th-century palace complex, at an elevation of 2,430 metres (7,970 feet), built by the Incas. During its heyday it was ruled over by long-reigning king Pachacuti Inca Yupanqui. It is located between the two large mountain peaks of Machu Picchu – which translates as 'Old Peak' – and Huayna Picchu – or 'New Peak' – in the Cuzco region of Peru.

Despite the complex – which consists of over 300 buildings, terraces, plazas and a cemetery – being constructed in the mid-15th to early-16th centuries and well known to the local population, it only gained global fame in 1911, when American archaeologist Hiram Bingham stumbled across it while searching for Vilcabamba – the 'lost city of the Incas'.

Since its 'discovery' the complex has been extensively excavated as it was in a ruinous and overgrown state and today it is Peru's number one tourist attraction in terms of money generated. While excavations have unearthed lots of unique art, sculpture and architecture, as yet archaeologists are still to determine why the settlement was abandoned. The presence of an extensive aqueduct system throughout the site has led some scholars to believe a climate change-induced lack of water could have been a major factor.

STRANGE BUT TRUE

SUN LOVERS

What did Machu Picchu's Incas use to tie up the Sun?

A A temple **B** A ritual stone **C** A long lasso

Answer:
The Intihuatana ritual stone at Machu Picchu is one of many stones arranged to point at the Sun during the winter solstice. The Incan people believed this stone tied the Sun in place along its annual path in the sky. Its name means 'hitching post of the Sun'.

DID YOU KNOW? *Machu Picchu was made a UNESCO World Heritage Site in 1983*

> "Any motion is detected by two mechanisms: a ring around the occupant's finger and a head plate"

How are bronze statues cast?

Explore the complex process behind this centuries-old art

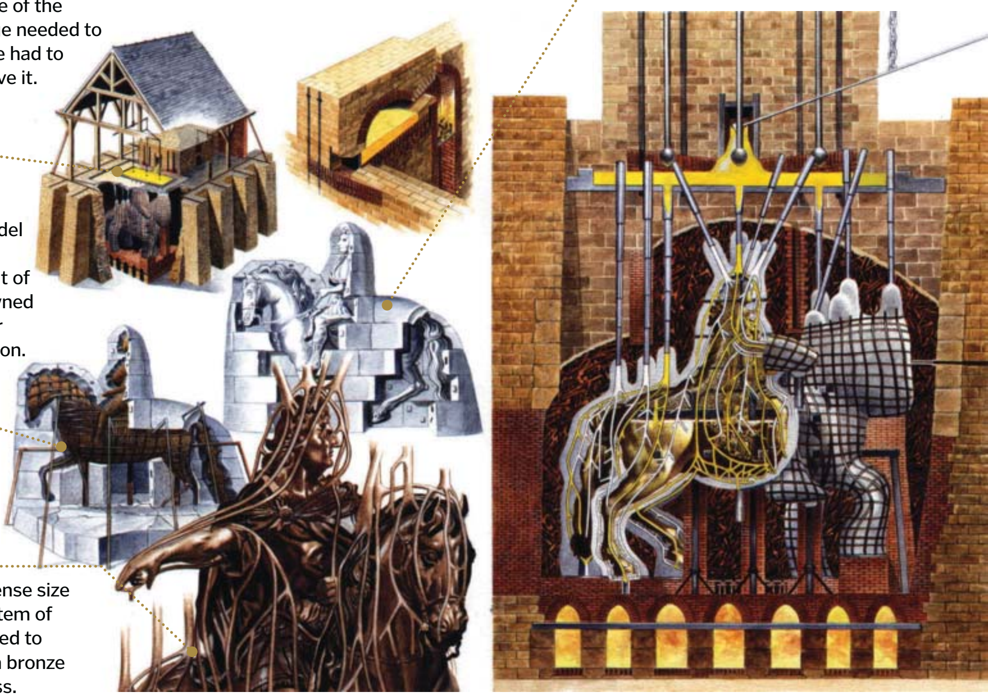
The first step in the casting of a bronze statue is to create a replica of the piece out of wood or clay. Secondly a lubricant such as oil is used to coat the statue followed by a thick layer of silicone rubber. After the rubber has hardened – a process that can take 24 hours – the coating can be removed from the replica, leaving a detailed mould.

Next, the mould is filled with hot wax. After being left to cool, the mould is taken off to leave a wax sculpture. After attaching the wax model to a device called a screw that channels molten bronze via a series of fine channels, the mould is dipped into a ceramic solution and covered with powdered silicon to strengthen it.

The internal wax mould is then melted in a steam oven, while the ceramic one is fired to provide the final mould. Bronze is heated to over 2,000 degrees Celsius (3,630 degrees Fahrenheit) prior to being poured into the mould, solidifying in 30 or so minutes. Lastly the ceramic layer is chipped and sandblasted away to reveal the bronze statue within.

Making Louis XIV on Horseback

See how this famous statue of the French king was created



Forge
Due to the scale of the model, the forge needed to melt the bronze had to be directly above it.

Model
The replica model for the bronze was created out of wood by renowned French sculptor François Girardon.

Pipework
Due to its immense size an intricate system of pipes was needed to feed the molten bronze into every recess.

Stone casing
The replica and castings were protected and structurally reinforced by a thick layer of stone.

What are life-preserving coffins?

How did this odd casket save anyone buried alive?

Very much a historical oddity, the life-preserving coffin was a special burial casket designed by Christian Henry Eisenbrandt in 1843 to allow those mistakenly buried alive to safely get out.

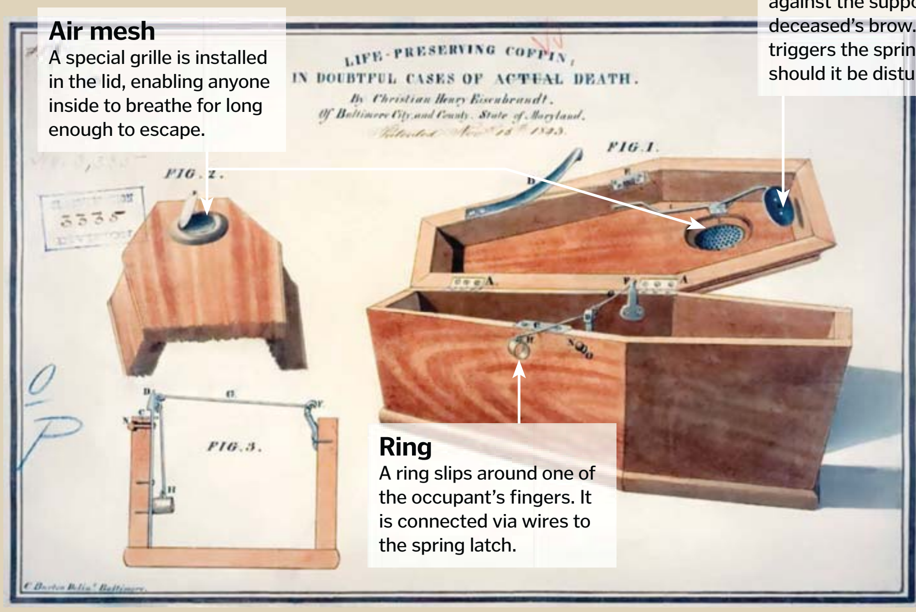
The system works by fitting the typical hinged lid with a series of levers and springs, which activate via motion-detecting devices in the coffin, ultimately releasing the latch.

Any motion is detected through two mechanisms: a ring slipped around the occupant's finger and a metal head plate. Both are connected by wires to the coffin's opening mechanism, with the slightest movement triggering the lid catch.

In addition to the opening mechanism, the life-preserving coffin also features a mesh in its lid which would supposedly provide a limited supply of air post-burial.

Back from the dead

Check out the key components of this unusual Victorian coffin



Air mesh
A special grille is installed in the lid, enabling anyone inside to breathe for long enough to escape.

Head plate
A head plate is placed against the supposedly deceased's brow. It triggers the spring catch should it be disturbed.

Ring
A ring slips around one of the occupant's fingers. It is connected via wires to the spring latch.

1. OLDEST

PS Waverley
The oldest seaworthy passenger-carrying paddle steamer in the world was built in 1946 and still operates around the British Isles.

2. SMALLEST

PS Monarch
The tiniest operational passenger-carrying paddle steamer in Europe, the PS Monarch is currently based in the south of England.

3. BEST

Belle of Louisville
Arguably the finest example of a paddle steamer on the planet, it often wins the annual Great Steamboat Race.

DID YOU KNOW? *The first steam-powered paddle-wheel boat was invented in 1774*

Paddle-wheel boats explained

HIW reveals how these uniquely propelled vessels worked and why they remain in use to this day

Paddle-wheel boats, which are typified by 19th-century paddle-powered steamships, are a unique historical form of marine transportation.

Their method of propulsion is what makes them stand out, with momentum provided by a rotating drum fitted with paddleboards. As the drum spins – with rotation powered by an engine (steam/diesel) or motor (electric/hydraulic) – the mounted boards act as oars, perpetually pushing against the water in a forward or backward cycle. Paddle wheels therefore act in a reversed manner to stationary, mounted water wheels, rotating in order to provide a motive force (thrust).

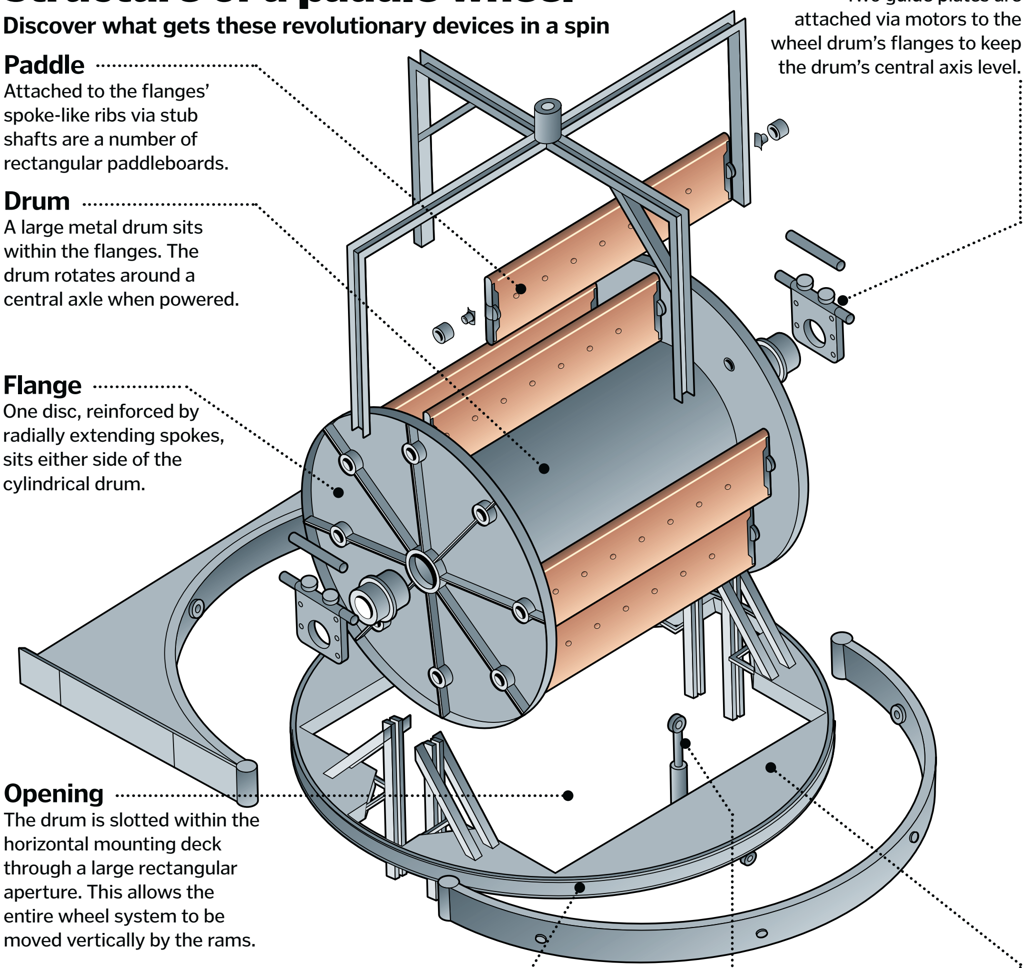
Paddle wheels are attached to vessels either at the rear (large single units) or at the sides (smaller pairs). The wheels, while sometimes exposed, are more often housed within a container called a paddlebox. The paddlebox both helps protect the marine environment (eg animals can't get caught up in the wheel assembly as easily) and also reduces the amount of splash while in operation.

The speed at which a paddle wheel spins is dictated by a large industrial gearbox, which allows for a selection of drum rotation speeds in addition to a single speed reverse. Certain paddle-wheel systems also come fitted with adjustable paddles. These work by separating each unit from the drum on axle-like rods – a mechanical layout that enables individual paddles to alter their angle upon contact with the water to be closer to vertical. By doing this, each paddle generates a greater amount of thrust, increasing overall efficiency and power.

Historically, paddle-wheel vessels were used as both ocean-going ships as well as riverboats. However, after the development of the modern screw propeller the paddle wheel was largely superseded due to its poorer efficiency in rough waters. Despite this, a number of paddle-wheel ships still operate today, where they are typically used to transport tourists.

Structure of a paddle wheel

Discover what gets these revolutionary devices in a spin



Paddle
Attached to the flanges' spoke-like ribs via stub shafts are a number of rectangular paddleboards.

Drum
A large metal drum sits within the flanges. The drum rotates around a central axle when powered.

Flange
One disc, reinforced by radially extending spokes, sits either side of the cylindrical drum.

Opening
The drum is slotted within the horizontal mounting deck through a large rectangular aperture. This allows the entire wheel system to be moved vertically by the rams.

Plate
Two guide plates are attached via motors to the wheel drum's flanges to keep the drum's central axis level.

Ram
A pair of rams enables the assembly to be moved vertically, so the wheel can be submerged at the desired depth in the water.

Rail
The wheel assembly can be rotated around the horizontal axis on a guide rail via a number of support rollers.

Deck
The vertical shift assembly which controls up-down movement of the wheel is supported by a circular deck.

Paddling into history

There is no surviving source that reveals precisely when the first paddle wheel was used to propel a boat, however records do indicate that the Romans were using ox-driven variants by the 4th century and that the Chinese were using them as early as the 5th century. Indeed, writings in the 7th-century *History Of The Southern Dynasties* – a historical compendium of China dating from 420-589 CE – state that Admiral Wang Zhene used paddle-wheeled ships in his 418 military campaign and that mathematician-astronomer Zu Chongzhi operated a paddle-wheel ship on the Xinting River in the late-5th century.

“Despite the reptile’s underwater dominance, the Plesiosaurus could not in fact breathe underwater”

Plesiosaurus

How It Works turns the spotlight on a ferocious marine reptile that dominated Earth’s oceans throughout the Early Jurassic

The statistics…

Plesiosaurus

Length: 4.5m (15ft)
Neck vertebrae: 40
Weight: 90kg (200lb)
Diet: Carnivore; eg fish, squid
Discovered: 1821

Plesiosaurus was an unusual long-necked marine reptile that lived in the Early Jurassic period (circa 199-175 million years ago).

This member of the sauropterygian superorder measured in at approximately 4.5 metres (15 feet) in length, sported a muscular and stocky body, a long and narrow neck, plus a short, stubby tail. Four large flipper-like limbs that attached in pairs to the torso allowed the creature to propel itself through the water at great speed, while a small head packed with rows of sharp, curved teeth ensured that once it got hold of its dinner there was no getting away.

Despite the reptile’s underwater dominance, the Plesiosaurus could not in fact breathe underwater like fish so had to surface to draw in air. Due to its size, however, it could spend a considerable length of time submerged, allowing it to repeatedly dart through shoals of fish and squid while hunting.

Plesiosaurus inhabited the shallow seas of what is now Europe, dominating the waters due to its size, agility and ferocity. Early in their history, this domination reached new heights when the order split-evolved into two main lineages: Pliosaurs and Plesiosaurids. The former developed a shorter neck and elongated head, while the latter developed a snake-like neck of epic proportions. This divergence allowed the species in each lineage to prey on an increasingly varied range of creatures, with some giants, such as Pliosaurus funkei (formerly ‘Predator X’), even capable of attacking other Plesiosaurs.

Plesiosaurus became extinct at the opening of the Middle Jurassic period (175 MYA), being superseded by its larger, more dominant relatives, like the Elasmosaurus. The Plesiosauria order, however, survived much longer, thriving worldwide until the Cretaceous-Tertiary (K-T) extinction event.

HEAD2HEAD

MARINE REPTILES

1. BIG

Ichthyosaurus

Despite looking a bit like a dolphin, Ichthyosaurus was actually a reptile closely related to lizards. It measured in at two metres (6.5 feet) long.

2. BIGGER

Kronosaurus

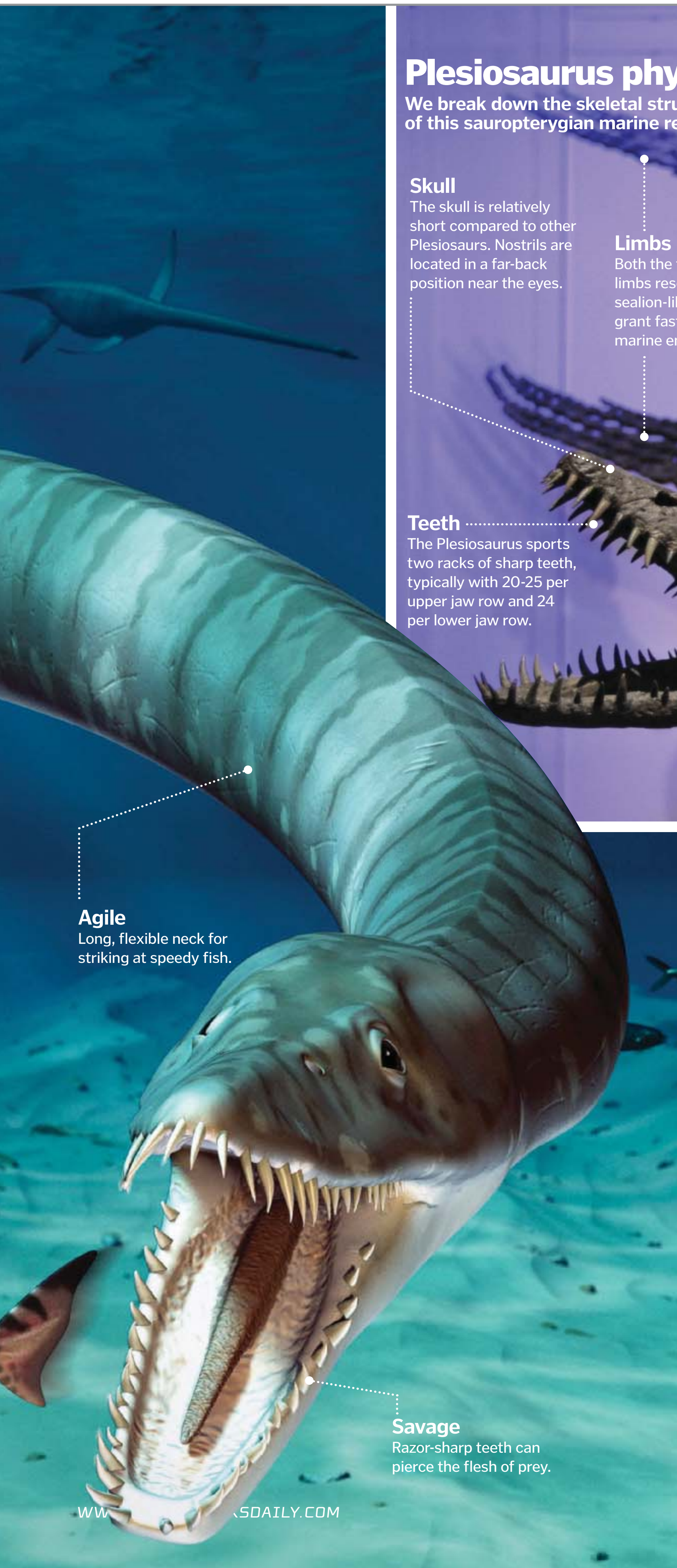
Measuring about nine metres (29.5 feet), with a skull exceeding 3.7 metres (12 feet), the Kronosaurus was around twice as big as the Plesiosaurus.

3. BIGGEST

Elasmosaurus

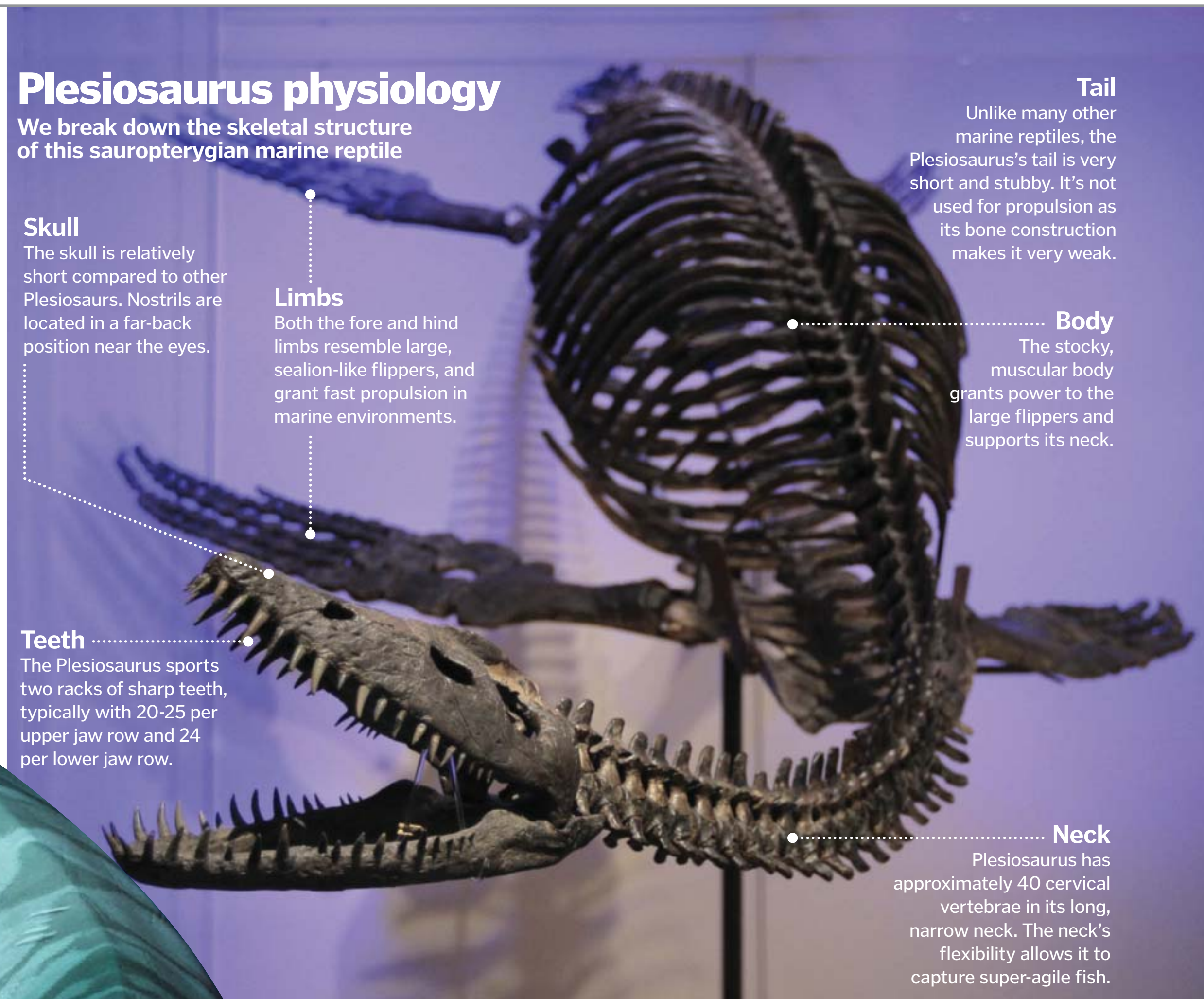
Elasmosaurus measured up to 13 metres (43 feet) and had 76 vertebrae in its neck. Fully grown, it was three times bigger than the Plesiosaurus.

DID YOU KNOW? *The name Plesiosaurus comes from the Greek for 'near to lizard'*



Agile
Long, flexible neck for striking at speedy fish.

Savage
Razor-sharp teeth can pierce the flesh of prey.



Plesiosaurus physiology

We break down the skeletal structure of this sauropterygian marine reptile

Skull
The skull is relatively short compared to other Plesiosaurs. Nostrils are located in a far-back position near the eyes.

Limbs
Both the fore and hind limbs resemble large, sealion-like flippers, and grant fast propulsion in marine environments.

Tail
Unlike many other marine reptiles, the Plesiosaurus's tail is very short and stubby. It's not used for propulsion as its bone construction makes it very weak.

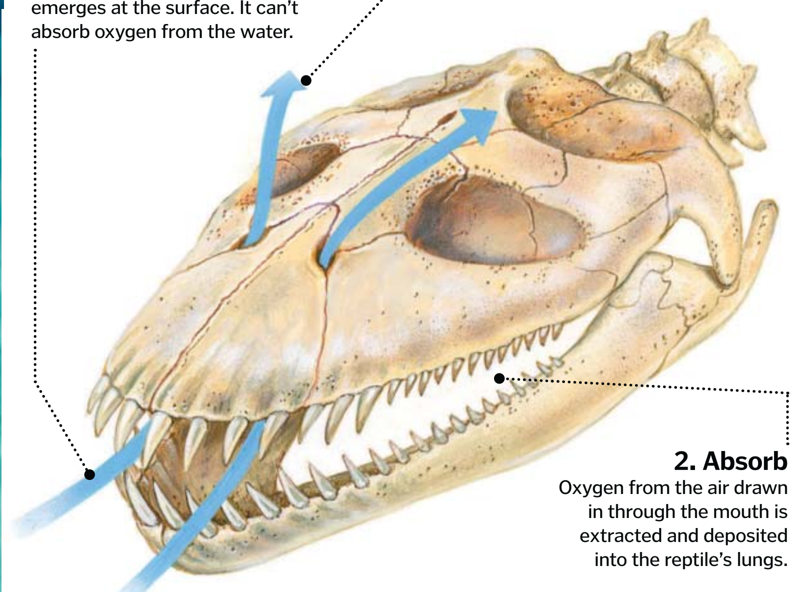
Body
The stocky, muscular body grants power to the large flippers and supports its neck.

Teeth
The Plesiosaurus sports two racks of sharp teeth, typically with 20-25 per upper jaw row and 24 per lower jaw row.

Neck
Plesiosaurus has approximately 40 cervical vertebrae in its long, narrow neck. The neck's flexibility allows it to capture super-agile fish.

How the beast breathed

Learn how this marine reptile obtained oxygen in a world dominated by fish



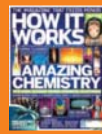
1. Inhale
Air is drawn in through the mouth when the creature emerges at the surface. It can't absorb oxygen from the water.

2. Absorb
Oxygen from the air drawn in through the mouth is extracted and deposited into the reptile's lungs.

3. Exhale
Spent air then exits the reptile through its backward-set nostrils, which are positioned close to the eye sockets.

BRAIN DUMP

Because enquiring minds want to know...



Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He's been writing about science and tech since before the web. His science-fiction novel *A Jar Of Wasps* is published by Anarchy Books.

Giles Sparrow

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in publishing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.

Rik Sargent

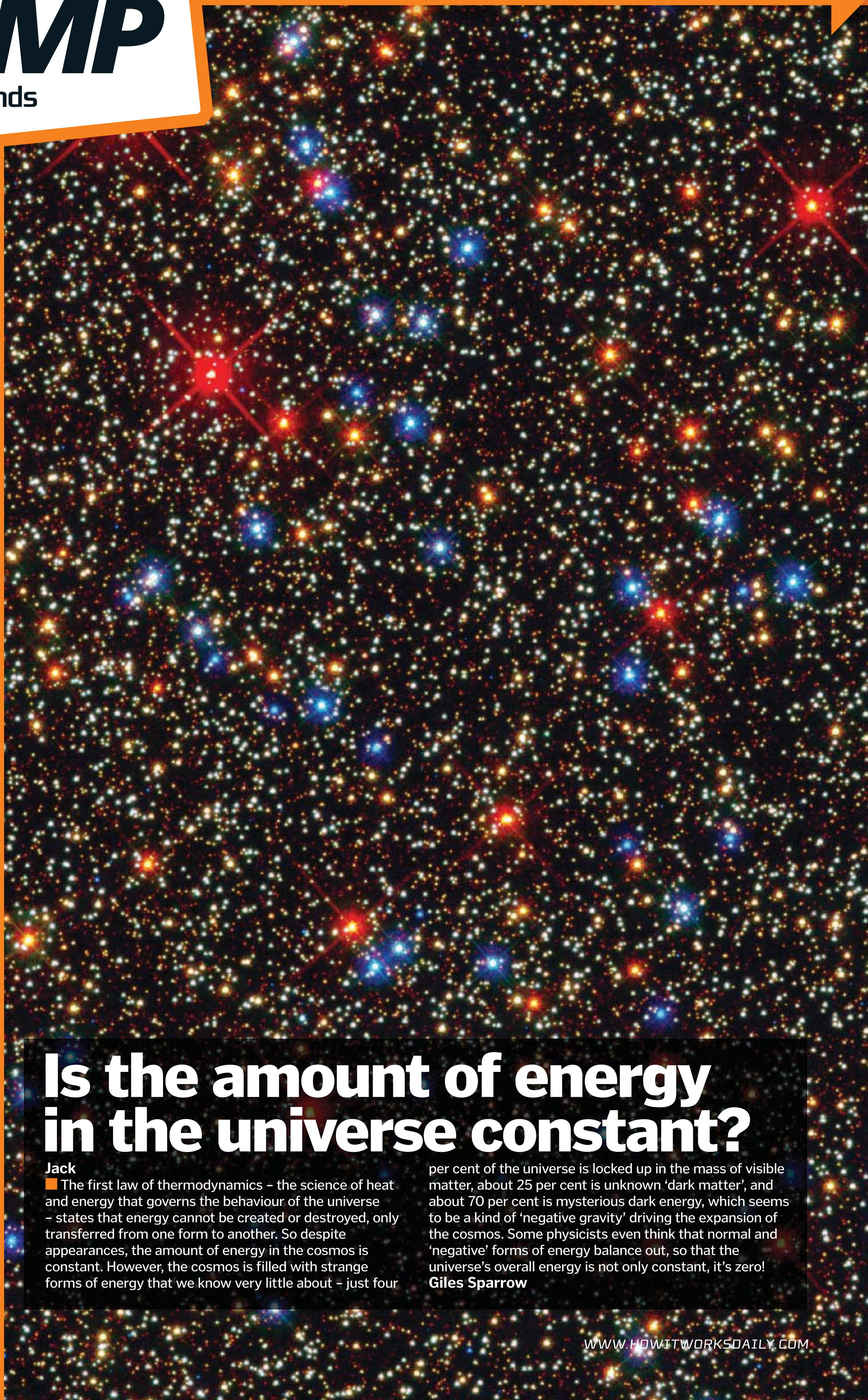
Rik is an outreach officer at the Institute of Physics, based in London, where he works on a variety of projects aimed at bringing physics into the public realm. His favourite part of the job is travelling to outdoor events and demonstrating 'physics busking'.

Tom Harris

Hailing from North Carolina, Tom is an experienced science writer who, over the years, has produced hundreds of articles which demystify complex subjects for both magazines and general knowledge books. In his spare time he's a keen dog rescue volunteer.

Dave Roos

A freelance writer based in the USA, Dave has researched and written about every conceivable topic, from the history of baseball to the expansion of the universe. Among his many qualities are an insatiable curiosity and a passion for science.



Is the amount of energy in the universe constant?

Jack

The first law of thermodynamics – the science of heat and energy that governs the behaviour of the universe – states that energy cannot be created or destroyed, only transferred from one form to another. So despite appearances, the amount of energy in the cosmos is constant. However, the cosmos is filled with strange forms of energy that we know very little about – just four per cent of the universe is locked up in the mass of visible matter, about 25 per cent is unknown 'dark matter', and about 70 per cent is mysterious dark energy, which seems to be a kind of 'negative gravity' driving the expansion of the cosmos. Some physicists even think that normal and 'negative' forms of energy balance out, so that the universe's overall energy is not only constant, it's zero!
Giles Sparrow

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What are hedgehog spines made of?

Alice Glossop

▪ They are modified hairs, made of keratin protein with a hollow shaft and a muscle for each spine so they can be raised when the hedgehog feels threatened. Hedgehogs are born without any spines but, within just a few hours, around 100 small white spines emerge from the skin and harden. After four or five days these begin to be replaced by tougher spines that are darker in colour but still quite short. Then at two to four weeks old, the hedgehog begins to get its final coat of adult spines. By the time it is fully grown, a hedgehog has around 8,000 spines.
Luis Villazon

Why is water transparent?

Sarah Tanner

▪ We can't see through walls because electrons in the structure absorb visible light. Some light reflects off the wall, but no light gets through. Radio waves – the same stuff as visible light with a longer wavelength – go straight through. This is because electrons in a wall don't absorb or reflect radio waves, due to their shape. Electrons in water act in a similar way to visible light so they don't absorb or reflect most of the light. Instead they allow it to pass through relatively unimpeded, absorbing wavelengths like infrared and reflecting invisible UV.
Rik Sargent

If the Sun's gravity reduced, what would happen to us?

Tim Swindle

▪ A sudden reduction in the Sun's gravity would trigger huge earthquakes as Earth shifted in its orbit, but it's hard to think of anything that could cause this. A slower reduction would simply lead Earth's orbit to slowly spiral outwards and slow down slightly. In fact, this is actually what's happening, as the Sun loses a bit of its mass each year, converting it to heat and light. But the effect is very small (about 0.25 per cent of the star's mass since its formation), and a gradual brightening of the Sun as it grows older means Earth stays warm.
Giles Sparrow

When was the Rialto Bridge in Venice built?

Rebecca Moore

▪ The Rialto Bridge is one of only four bridges that span the Grand Canal in Venice, Italy. The stone bridge was commissioned in the late-16th century to replace the previous wooden structure, which was prone to collapse. Blueprints were submitted by the most eminent architects of Renaissance Italy, including Michelangelo, but the commission went to the relatively unknown, Swiss-born Antonio da Ponte ('ponte' is bridge in Italian) in 1588, whose revolutionary design featuring a single broad arch was completed in 1591. Today, the Rialto Bridge is one of the most visited tourist sites in the city, featuring an arcade of shops and excellent views of the famous gondolas passing beneath.
Dave Roos

What things can make us feel dizzy? Find out on page 86

BRAIN DUMP

Because enquiring minds want to know…

Which is the tiniest shark?

Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

What sort of materials could be mined from asteroids?

Frederick Barret

■ Asteroids could be a source of many heavy elements rare in Earth's crust. Our world and the asteroids actually contain a similar mix of materials, but Earth's gravity pulled most of these elements down to its core during its early, molten phase. Asteroids never separated in the same way, so heavy elements are plentiful near the surface. As well as rare minerals, asteroid miners also hope to extract commonplace materials such as water, hydrogen and oxygen; the ability to produce rocket fuel, air and water beyond Earth's gravity could start a revolution in space exploration.
Giles Sparrow

If you add more sides to a Rubik's cube, does it still work the same?

Shaun

■ Yes. The Megaminx is a 12-sided version of the traditional six-sided Rubik's cube. As with the cube, the goal of the Megaminx is to solve the puzzle by isolating a single colour on each face. Also like the cube, the centre tile on each Megaminx face doesn't move and indicates the native colour of that face. Although there are a mind-boggling 1.01×10^{68} possible tile combinations, experienced solvers say the basic technique is the same. The record for a Megaminx solve is 42.28 seconds compared with a lightning-quick 5.66 seconds for the 3x3x3 cube.
Dave Roos

What causes dizziness?

Cait Mallin

■ Dizziness – sometimes referred to as lightheadedness – can be brought on by a wide range of factors. In general, people who feel dizzy describe it as a feeling of being off-balance, however other experiences such as spinning room-type sensations are also common.

The most frequent causes of dizziness include viral illnesses that affect the ear – often resulting in vertigo, migraines, hyperventilation (and thus lack of oxygen) brought on through stress, as well as low blood sugar levels. Despite many people feeling dizzy at odd moments throughout their day-to-day lives, the good news is that in most cases it's not an indication of a serious underlying issue. However, a doctor should always be consulted with any particularly intense or persistent cases.
HIW

Did Richard III order the murder of the Princes in the Tower?

Bill Huxton

■ When King Edward IV died in 1483, his eldest son – 12-year-old Edward – was named the new monarch. However, Edward IV's younger brother Richard stopped the coronation, arguing that Edward and his nine-year-old brother (another Richard) weren't legitimate heirs because Edward IV had married another woman before marrying the boys' mother. As a result, he claimed the throne for himself, as Richard III, while his nephews remained confined in the Tower of London.

Soon after, when the two princes went missing, rumours spread that the king had killed them in order to eliminate potential rivals. Centuries later, the 1674 discovery of two skeletons buried under a staircase in the Tower of London set the story in stone.

There's good reason to doubt the story, however. First, the murder would have been out of character for Richard, who was close to his brother Edward IV and likely protective of his nephews. The Tower of London wasn't a prison at the time after all, but a secure palace.

Second, the tale comes to us through the Tudors – bitter rivals who later killed Richard III on the battlefield and claimed the throne. They had motive both to smear Richard and to get rid of the princes. The skeletons are no smoking gun, as people had been burying corpses on the Tower of London grounds for centuries.

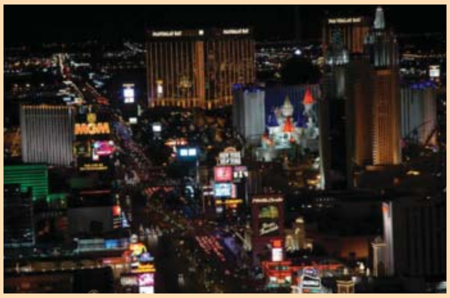
We could potentially confirm or disprove the identity of the mystery skeletons by comparing the DNA from those remains – now interred in Westminster Abbey – with the skeletons of Edward IV and his wife Elizabeth in Windsor – or even Richard III, recently found under a Leicester car park. Queen Elizabeth hasn't granted permission for the examination to take place though.
Tom Harris

Where does Vegas get its power from?

Samuel Hopely

With all its pomp and glitz, Las Vegas is infamous for its excess. In 2011, the state of Nevada consumed more than 28 million megawatt-hours of power, and all that juice has to come from somewhere. Like every other US city, Las Vegas draws power from a national electrical grid supplied by more than 6,000 power-generating units fuelled by coal, natural gas, oil, the Sun, moving water and more. The only exception is the sprawling new CityCenter hotel and casino complex, which is so large that it boasts its own 'off-the-grid' electrical powerplant (and its own fire department). The Hoover Dam, only 48 kilometres (30 miles) from Las Vegas, is one of the largest dams in the world, and generates more than 4 billion kilowatt-hours of electricity annually – 95 per cent of which is consumed in other US states.

Dave Roos



How far would an icicle have to fall to harm us?

Tristan McCallum

An icicle's piercing power depends on a few variables. The force of impact depends on the icicle's momentum (mass multiplied by velocity). A higher drop means greater velocity as the icicle has more time to accelerate, but if it's big enough, it will have adequate momentum even if it falls just a short distance. The sharpness of the icicle, meanwhile, dictates the concentrated force at the point of impact, which determines if it could pierce skin. The TV series *MythBusters* staged a plausible rooftop icicle incident scenario. In the experiment, they successfully pierced a steak with a 45-centimetre (17.7-inch) icicle falling from 4.6 metres (15 feet).

Tom Harris

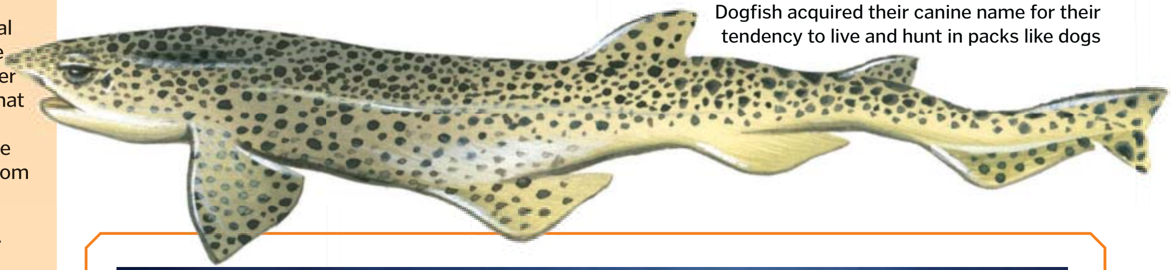
Which is the smallest shark?

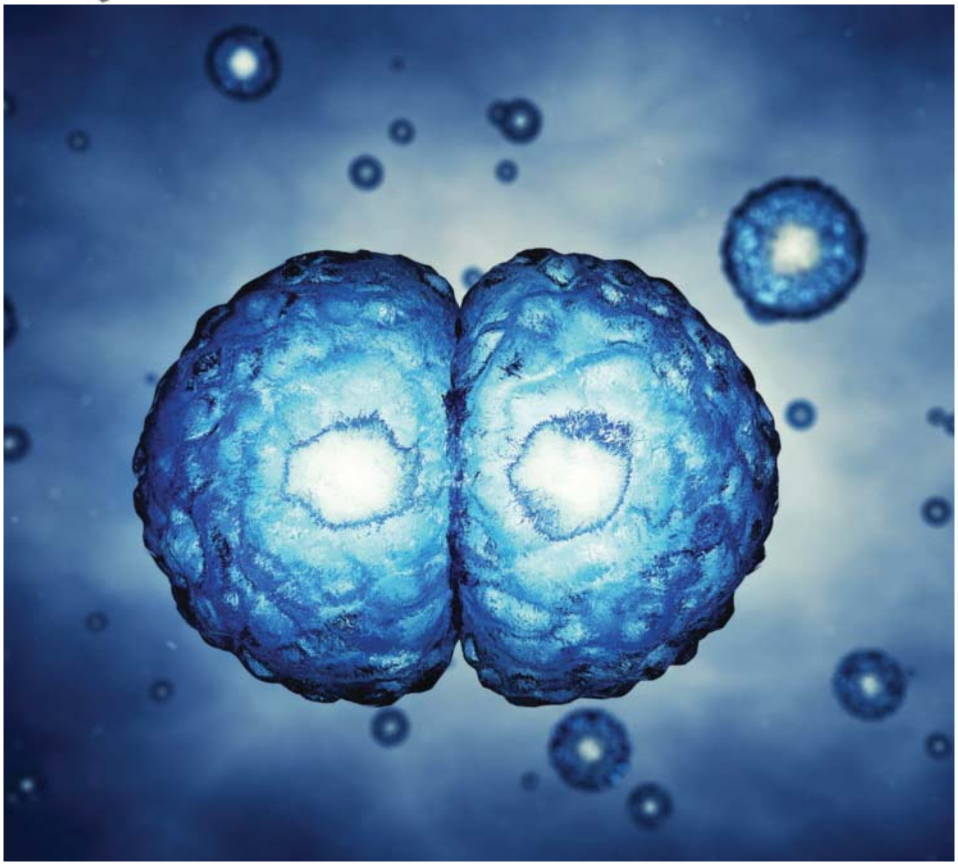
Kathryn Atkins

Dogfish are technically sharks because they belong to the subdivision Selachii, which comprises all modern sharks. The smallest dogfish on the planet is the dwarf lanternshark (Etmopterus perryi). It only lives in the warm waters of the Caribbean, off the northern coast of Colombia and Venezuela, and it reaches just 16 or 17 centimetres (6.3-6.7 inches) long when fully grown. They look just like larger shark species, with the same elongated eyes, pointed nose and asymmetrical tail. They are called lanternsharks because they have light-emitting organs in their skin that produce vivid-coloured markings while the fish is alive. Some of these markings attract mates, but others replace the sunlight shining from above so that the lanternshark doesn't present a dark silhouette to any predatory fish which might be below, acting like an 'invisibility cloak'.

Luis Villazon

Dogfish acquired their canine name for their tendency to live and hunt in packs like dogs





Are cell mutations always bad?

Michel Vangelatos

A mutation is a change in the genetic material of an organism. We are made from trillions of cells, each with a nucleus composed of DNA – a set of instructions that tells the cell what to do. Cells copy themselves with astonishing accuracy, but every now and then a piece of code is copied incorrectly. This is largely due to natural radiation bombarding us on a daily basis and interacting with our DNA. This incorrect piece of code can become a permanent change in the DNA – a mutation that can be copied further. Mutations are rarely harmful though. Indeed, most mutations go unnoticed, as the body has mechanisms to stop a cell copying itself when a mutation occurs. Sometimes mutations can even benefit organisms and promote diversity in a species. When a mutation allows an organism to cope better with an environmental stress, it will be passed on to future generations through natural selection.

Rik Sargent

Why do cold things give us brain freeze? Find out on page 88

BRAIN DUMP

Because enquiring minds want to know...

Which bug can live the longest?
Find out on page 89

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

How old is the Andromeda galaxy and how did it form?

Richard Davis

■ As the brightest and closest spiral galaxy beyond the Milky Way, the Andromeda galaxy has been intensively studied, but it's only in the last few years that astronomers have really got to grips with its origins. Galaxies come together in stages, and the properties of Andromeda's oldest stars suggest that they originated in smaller 'protogalaxies' which began to coalesce into larger structures about 10 billion years ago. 2 billion years later, the young and rather shapeless Andromeda started to collide with another substantial protogalaxy. This merger process took 3 billion years and created Andromeda's characteristic bright central bulge of stars and large extended disc – some stars flung off in the process still form distinctive streams wrapped around the main galaxy. Andromeda has continued to grow by cannibalising smaller galaxies until quite recently, and infrared images of the dust in its disc suggest its most recent victim was swallowed just 100 million years ago.
Giles Sparrow

Why can cold drinks give us a headache?

Thomas

■ We may finally have an explanation for this phenomenon, known variously as ice-cream headache, brain freeze, cold-stimulus headache and, more officially, sphenopalatine ganglioneuralgia. A team of researchers led by Harvard Medical School's Dr Jorge Serrador asked 13 brave volunteers to sip ice water through a straw aimed directly at the roof of the mouth, while transcranial Doppler (TCD) ultrasound captured the flow of blood in their brains. In 2012, the team published the results: just before the headache hits, blood rushes through the anterior cerebral artery in the brain. The evidence isn't conclusive, but it's likely we experience this increased pressure as headache pain. The researchers suspect that cold food or drink may briefly cool the blood, and the increased flow is the body's way of warming things up again to keep the brain at an optimal temperature.
Tom Harris

Why does grease make paper see-through?

Chris Basterfield

■ Paper is made up of thousands of cellulose fibres separated by tiny pockets of air. When light meets paper, this tangled mesh of fibres and air scatters the rays in all directions. The scattering is due to refraction – the bending of light as it moves between two materials/mediums. In paper, light goes from fibre to air and back so many times that it scatters a lot, and so a coherent image cannot be seen through the sheet.

When grease saturates paper, however, it essentially fills in all the gaps of air. Light moving between cellulose fibre and grease does not bend as much as light moving between cellulose fibre and air. As a result, the light scatters much less; instead it moves through the paper in roughly a straight line, allowing an image – albeit a blurry one – to form.
Rik Sargent

Mary Shelley's take on Frankenstein might be farfetched, but scientists have already created a new form of microbial life

Is it possible to make a real-life Frankenstein?

Geraint Eickermann

In a sense, yes, it is, though the 'creature' is a bit tamer than Frankenstein's monster from the famous novel. In 2010, a team of scientists led by biologist Craig Venter used a computer to replicate the genetic code of a simple bacterium – Mycoplasma genitalium – adding a few small tweaks as a watermark signature. Then they implanted the man-made genome into an empty cell of another bacterium species – Mycoplasma mycoides. The resulting new bacterium, nicknamed Synthia, successfully replicated itself, making it, arguably, alive. They didn't make it 'from scratch', but the result was an original man-made life form. In the near future, man-made creatures might yield new food, fuel, medicine and pollution remedies, but it remains a very controversial field.
Tom Harris

Which insect has the longest life span?

Laura Bale

The adult, flying form of most insects lasts for just a few weeks or months but this is only a small fraction of the insect's total life span. The adults are generally adapted only for mating and eat little or not at all. The larval form will have spent a year or two hiding away in a pond, underground or inside a tree/rotting log, eating and growing. The Magicicadas of eastern USA are a genus of cicada that spend 13 or 17 years underground (depending on the location) before they all emerge as adults in a single, synchronised wave lasting a couple of months. This is nothing compared to termites though. Although the smaller workers are only around for a year or two, a termite queen can live for up to half a century!
Luis Villazon

Can weightlifting at an early age stunt growth?

Alex Grieve

Weightlifting for young people – with correct supervision and technique – has no bearing on how they grow. When a ten-year-old does push-ups, or jumps up and down, they are essentially lifting around 30-50 kilograms (66-110 pounds). However, it's important to understand that growth plates in young people are not fully developed. Growth plates are soft areas of cartilage around the ends of bones, and they regulate growth in children and young teens. They do this by being the last part of the bone to harden, allowing the bone to develop to the desired length. Growth plates are more vulnerable to fractures in youngsters. Excessive weightlifting with poor technique could damage these plates, affecting growth.
Rik Sargent

What is the capacity of a Wii U game?

Ben King

Nintendo launched its latest gaming system, Wii U, in November 2012. The upgrade to its revolutionary Wii console, which hooked the world on motion-capture gaming, is designed to be an all-encompassing entertainment hub, complete with a tablet-size controller that doubles as a second viewing screen. Among the Wii U's advances is a proprietary disc format for its games. The round-edged optical discs, which are the same size as DVDs, hold 25GB of data, sufficient for 1080p hi-def games. That's the same capacity as PS3 games, which are stored on single-layer Blu-ray discs, but a lot more than the 8GB that can be stored on Xbox 360 games.
Dave Roos

Network audio players

We test out three streamers that can take your home audio to another level

Pioneer N-50

Price: £379/$699
Get it from: www.pioneer.eu
A drop in the street price of over £100 from the RRP is no reflection on the quality of this network audio player. That much is evident in the minimalist finish alone, the clean lines and brushed aluminium aping the look of a high-end device, while cramming in a commendable number of features too. The back of the unit allows for myriad connections: analogue out, digital optical and coaxial in/out, asynchronous USB for rigging directly to a PC, a socket for a Bluetooth adaptor and 10/100 LAN for wiring to a router. There's iOS functionality and AirPlay too – a simple case of pushing a button on your remote to stream from your Apple device. It's all pretty easy to use actually. Access to network music on PC at up to 192kHz/24-bit playback just requires changing a single setting in Windows, and navigating your files is painless on the LCD panel, which even displays album art. The only catch is the lack of wireless functionality. For that, you'll need to upgrade it with an AS-WL300 wireless box (costing around £50).

Verdict: ★★★★☆

Naim UnitiLite

Price: £1,650/$TBC
Get it from: www.naimaudio.com
Remember when we said the Pioneer N-50 was aping the look of the high-end market? Well, forget we said that, because this piece of home-grown audio kit looks nothing like the N-50; and though the UnitiLite isn't the heavyweight of the Naim range, the price tag means it's only for committed audiophiles. The UnitiLite has a rather boxy, retro look – the lime green logo and LCD display the only obvious indication that it's not a Nineties CD player. Any doubts vanish once you turn this beauty on though. The idea of the UnitiLite is that it's a comprehensive music device, combining CD player with 192kHz/32-bit streamer that can play every file format conceivable. It also boasts iOS connectivity, USB/coax/optical/network/wireless inputs and 50W per channel output. It sounds great for an all-in-one solution… Scrub that: it just sounds great – especially considering you won't need a separate power amp. It might not quite have the welly for a huge venue, but for a typical home network setup, this is all the streamer you'll ever need.

Verdict: ★★★★☆

Yamaha RX-V673

Price: £499.95/$649.95
Get it from: http://yamaha.com
Towards the top of Yamaha's RX-V series is the RX-V673, a formidable home cinema amplifier that offers a host of features and all-round value for money. This box of audio delights has a distinctive Yamaha look to it: a glossy black finish with large buttons and chunky volume dial. Flip the box around and you'll be dazzled by the array of inputs and outputs. Alongside Apple AirPlay, the RX-V673 includes six HDMI inputs (one is on the front), 4K pass-through, optical, component and surround-sound options. Plug your speaker system, console or TV in and you're just a couple of button-presses away from a very satisfying audio experience. The RX-V673 is DLNA certified, comes with internet radio and has the built-in YPAO reflected sound control feature. It isn't quite in line with the high-end UnitiLite or dedicated network streaming N-50, but taken as part of a home cinema system – and at less than a third of the price of Naim's offering in this test – we have to hand the gong to Yamaha.

Verdict: ★★★★★

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Survive a snakebite

Avoid hiss-teria with these top dos and don'ts should you get bitten…

1 Don't get bit

This might seem obvious, but many victims of snakebites invite them by wearing the wrong clothes and/or acting recklessly while out walking. Appropriate clothing includes lined trousers (eg jeans), gaiters and high-lined boots. As a general rule leave no area of skin beneath the waist exposed. In terms of behaviour, do not overturn random logs or rocks as snakes frequently shelter under these and, if you are scrambling over rocky ledges, be mindful where you place your hands.

2 Stay calm

Sometimes a snakebite is unavoidable. If you do get bitten the first rule to remember is that you should remain calm. This isn't just common sense. By entering a state of panic you increase your heartbeat and general blood circulation around the body – this in turn will increase the rate at which venom is distributed and/or exacerbate bleeding. Just keep in mind that the vast majority of snakebites are very slow acting and so you have plenty of time to seek medical assistance.

3 Don't suck

A common myth is that by immediately sucking on the wound you are able to draw the venom out. While no doubt some of the venom would be extracted this way, you are really just trading one benefit for additional complications, such as necrosis (tissue death) of the bitten area as well as potential infection in your mouth. Further, by sucking on the bite you will heighten blood flow, increasing the bleed-out rate. It's best to avoid using venom suction kits for the same reasons.

4 Clean the bite

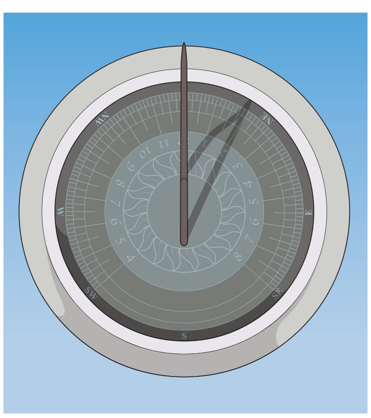
If possible, prior to doing anything else bar calling for support, you should clean the wound with a delicate application of cold water. Importantly, you shouldn't scrub or press heavily on the bitten area of skin as this will likely also lead to necrosis and increased blood loss. If this is done correctly then bleeding should stop after a minute or so. If the bleed out remains constant or is gushing, the snake has probably hit an artery – ignore this step and move straight on to the next.

Read a sundial

Take a minute to learn how to read these outdoor timepieces

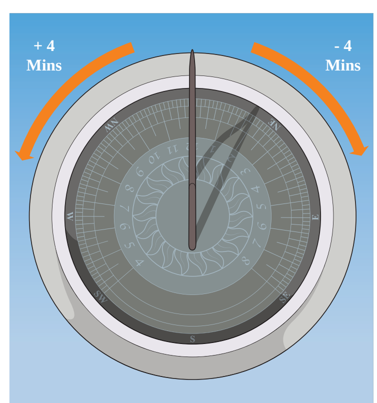
1 Read the shadow

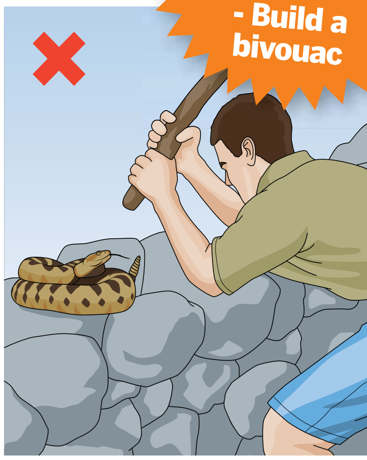
The shadow extending from the sundial's gnomon – that is, the wedge-shaped triangle in the centre – will extend from its base all the way to the dial's rim. However, at most times of day the shadow will have two pronounced edges, with each hitting a different time on the plate. The correct way to read the shadow is to identify the shaded edge that's farthest from the gnomon.



2 Adjust for location

Just because the farthest edge of the gnomon's shadow is pointing to two o'clock doesn't mean that is the time. This is because of the size of regional timezones and the fact the dial is showing solar time, not clock time. As such, for every degree of longitude the dial is west of its timezone's centre, four minutes should be added, and vice versa for every degree east of centre.





5 Don't use a tourniquet

Regardless of whether it's a shallow or deep bite, do not use a tourniquet (tight bandage) on the wound. This will increase necrosis rapidly and, in severe cases, could even result in amputation of the limb. To stop serious bleeding, rather than a tourniquet, use a constriction band. A constriction band can be bought or fashioned out of cloth and will reduce blood flow rather than stopping it. This will both help to stem the bleeding and also slow the passage of the venom around the body.

6 Leave the snake

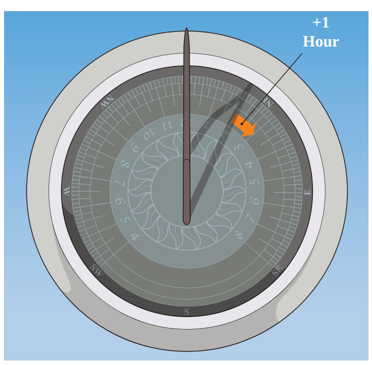
Lastly, don't kill the snake. A widely held myth is that for a doctor to treat your bite they need to know which snake bit you, as that way they can administer the correct antivenom. This is false, with modern antivenom often polyvalent (ie it counters most venoms in a certain region). Further, by going after the snake you only waste time and make yourself vulnerable to additional bites. Simply back slowly away from the creature until at a safe distance and then head for help.

In summary...

Getting a snakebite can be distressing, but if you ignore the myths and don't panic, your survival chances are very high. Ensure you are well protected when trekking in areas where snakes are common. Be sure to tread carefully and stick to clear paths as much as you can. If you do get bitten, stay calm to keep your heart rate low and do not exacerbate the injury by sucking or applying excessive pressure to the wound. Finally, leave the environment as quickly as possible, avoiding additional confrontations. It's also worth noting that many snakes are not even venomous, but it's essential to get bites checked out just in case.

3 Adjust for daylight savings

Lastly, an allowance needs to be made to account for daylight savings if the reading is taking place in summer – the Sun, after all, doesn't know anything about human time! To do this, you simply have to add an additional hour to the time worked out in step 2.



In summary...

Reading a sundial is easy provided you know your positional longitude in your timezone – and you can find this out online in seconds. Then you just read off the gnomon's shadow and allow for the time of year.

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NEXT ISSUE
- Hunt for fossils
- Build a bivouac

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 On which Chinese river did astronomer Zu Chongzhi use a paddle-wheel boat?

2 What was the average weight of a plesiosaurus (pictured) in kilograms?

3 How many light years from Earth is the Large Magellanic Cloud?

4 What type of battery is commonly used in cars?

5 How many times more sensitive is a dog's nose to a human's?

6 What is the muzzle velocity of the Phalanx close-in weapon system (m/s)?

7 Europa is a moon of which planet in the Solar System?

8 Which historical Chinese character is often depicted in a wheelchair?

9 Which galaxy is both the brightest and closest to the Milky Way?

10 How many years can a termite queen live?

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ISSUE 44 ANSWERS

1. Tonsillectomy **2.** Christian Doppler **3.** Bikes **4.** 71 **5.** Khartoum **6.** 48km/h **7.** Carrack **8.** 1056 **9.** 214,200km/h **10.** Bronze Age

INBOX

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This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

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So, naturalists observe a flea;
Has smaller fleas that on
him prey;
And these have smaller still
to bite 'em,
And so proceed ad infinitum

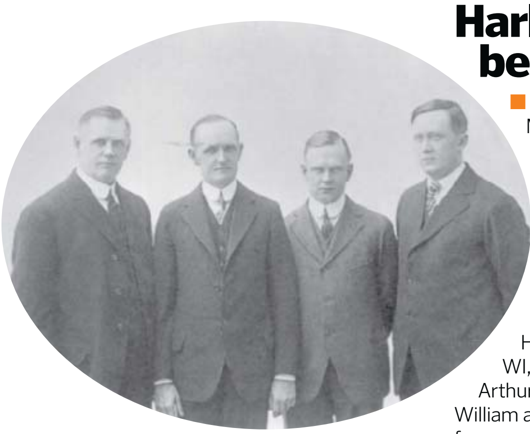
From *On Poetry: A Rhapsody*
by Jonathan Swift

Letter of the Month

Biting criticism

Dear HIW,
In issue 43 of How It Works, you have an article headed up '50 amazing facts about science'. Number 24 states that 'Every living thing has at least one parasite living in/on it'. Given that parasites are themselves living things, this suggests that each parasite has its own parasite in a recursive biological storm of parasites. The conclusion to be drawn from this assertion is that the Earth contains an infinite population of parasites, with a relatively insignificant community of non-parasitic hosts.
Jeff Pratley

Hi Jeff – thanks for your letter, it gave us all a chuckle. Interestingly, the 13 families and 30 genera of bacteriophages are thought to be the most abundant life form on the planet. Indeed, there are an estimated 100 million species of these organisms weighing an incredible 1 billion tons; to put that in perspective, it's over three times more than the weight of the entire human race! It's not quite ad infinitum, as you (or Jonathan Swift) might say, but as 'bugs' that live in bugs that live in other living organisms can be found all over the world, to us they might as well be!



The Harley-Davidson founders from left: William A, Davidson; Arthur Davidson; Walter Davidson Sr; and William S Harley

Harley's humble beginnings

Dear How It Works,
Most interested in the Harley-Davidson article in the latest edition [issue 44] and thought you would be interested in a bit of extra information about the motorcycle company. It is amazing how many companies started in 'sheds'…
Arthur Davidson and William Harley both worked in Milwaukee, WI, at a metal fabrication company. Arthur was a pattern maker and William a draughtsman. They worked from a wooden shed – 3 x 4.6 metres (10 x 15 feet) in size – and the famous bike emerged. It shows that from small beginnings great things can emerge. Avery scales and Black & Decker's Workmate also started life in sheds.
Malcolm Turner

Food for thought

Hello HIW,
Your recent article on recycling (issue 42) has set me thinking. Clearly there is potential for more recycling. This is good, but it would be even better if we reduce waste in the first place. Newspapers make up a large proportion of our waste, and a typical paper is so large that much of it goes into the bin without having been read. It would help if more papers published a concise edition. Another example is food waste. This could easily be reduced by careful purchasing, thereby saving not only the food itself, but also packaging, and the energy used to produce and distribute our food.
Roger Collison

Do the maths

Hi,
I'm a student from Pakistan. I got my hands on your magazine a couple of months ago in the flea market; it's not available new here – only at the second-hand stalls. I must say, this magazine rocks! It's the best mag I've ever read. From information to presentation, everything about it is spectacular. Sadly, I don't get enough pocket money to subscribe: pounds into rupee makes a large sum! I have issues 20, 22, 27, 28 and 40. If possible, I would like you to feature a topic on the role of mathematics in entertainment – that would be great.
Sabeen

Even eminent scientists like Lord Kelvin got it wrong sometimes…

Hot topic

Dear HIW team,
In issue 43, you explain why lava is red, referring to professor of natural philosophy at Glasgow University Lord Kelvin's famous theory that Earth's molten globe is still cooling down from our planet's original formation. Kelvin used this theory – together with a key assumption (incorrect) that rocks melt at 4,000 degrees Celsius [7,232 degrees Fahrenheit] – to date Earth to no more than 400 million years in 1862. Rutherford and Soddy's discovery of the law of radioactivity decay in 1902, however, eventually led in the Thirties to a consensus that radioactive decay is still at work heating up the Earth's core. Why lava is red is a fantastic question, and the answer is an incredible journey.
Lucy Borland

Heard it on the radio

Hello,
I would like to challenge an article in issue 41, page 22 ['Industrial Revolution: Inventions'], which states Guglielmo Marconi was the inventor of radio. May I point out that in actual fact – although sadly not widely known – it was an Englishman, Sir Oliver Lodge, who first sent a transmission signal on 14 August 1894. This was one year before Marconi.

Lodge sent a signal with an induction coil and spark gap transmitter from the Clarendon Laboratory to an Oxford University lecture theatre: a distance of around 55 metres (180 feet). This public demonstration was recorded at the time, but Lodge didn't have the business acumen and thus did not patent it. Marconi, however, did patent it and has been given the credit ever since.

The Royal Society unveiled a plaque at the very site where Lodge's demonstration took place with Lodge's grandson present. I think it would be fitting for your magazine – and hopefully your readers – to give a huge round of applause for Sir Oliver Lodge and his invention. I wonder how many times this question has been disputed in a pub quiz… Thanks for a great magazine.
Steve Clarke

> "The Royal Society unveiled a plaque at the very site Lodge's demonstration took place"

What's happening on… Twitter?

We love to hear from **How It Works**' dedicated readers and followers, with all of your queries and comments about the magazine and the world of science, plus any topics which you would like to see explained in future issues. Here we select a few of the tweets that caught our eye over the last month.

Adam Martin @TedTheLadsDad
Thanks so much **@HowItWorksmag** for the awesome binoculars. Can't wait to take the boy out on his first expedition to Dartmoor this weekend! :D

Emma Walters @emmav6
@LilinhaAngel **@HowItWorksmag**
Thank you, happy happy happy :)

Ryan Evans @ryanevans06
@HowItWorksmag
Just finished issue 43, first time I read your mag – loved it! The map of the Battle of Little Big Horn was fantastic

All About Space @spaceanswers
@HowItWorksmag
#FF We love space, but also @HowItWorksmag @iCreateMagazine @lgrobot @LinuxUserMag @WebDesignerMag @knowyourapps @SciFiNow @GreatDigitalMag

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How are video/audio transmitted down wires of various types and how do electron microscopes work?

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Dell recommends Windows.
This is the story of
Thomas and the alternate universe.
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With his laptop, he created a graphic novel where
anything was possible.
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